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DR. FRANKLIN AS THE ENGLISH SAW HIM.*†

BY

CONYERS READ, Ph.D., Litt.D.,

University of Pennsylvania.

Benjamin Franklin during the greater part of a long life regarded himself an an Englishman. Up until the very verge of the American Revolution he insisted that America was a part of England, at least as much a part of it as Scotland was, and that any disposition on the part of either King or Parliament to deprive Americans of their rights as Englishmen was not only wrong in morals but wrong at law. His father was an Englishman born, and his interest in his English family connections is manifest throughout his life, even when he was a great fellow in London and they were poor country folk in Northamptonshire.[1] He spent two years in England before he was twenty, and nearly twenty years in England after he was fifty. His love for England was beyond question. His famous letter to Polly Stevenson on the subject in 1763 is

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[1] On his visit to his ancestral home, cf. his letter to his wife of 6 September, 1768 in Smyth, "Writings," III, 451–4.

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almost too familiar to bear repetition,[2] and everyone knows his famous panegyric upon Scotland.[3] After he was fifty he travelled over a great part of England and visited Scotland and Ireland as well.[4] When he was close to sixty he seriously intended to move to England permanently[5]—and he was ready to consider a permanent appointment in England three years after the passing of the Stamp Act—though somewhat fearful that "old trees can not be safely transplanted." [6]

Franklin was not only English in his origins and in his sympathies, he was English also in his ways of thought and in his standards of behavior. And much which we call American in him was English by derivation, by translation—English, we might say, as modified by the frontier. Franklin was in his beginnings essentially a frontier type, an adventurer, a rebel against the conventional order. He declined to follow the pattern his father had set for him, he declined to subordinate himself to a less intelligent elder brother. He ran away from Boston to Philadelphia with a fine confidence in his ability to get on anywhere. And he had not yet got himself well-established in Philadelphia before he ran away again, this time overseas on a wild goose chase. There can be no doubt about his abounding physical vitality, the sound mind in the sound body. Indeed his superabundant physical vitality probably explains his many youthful falls from grace. But his interests even at the start were too definitely of the mind to succumb for long to the purely animal interests of the body. And there was besides a very definite and a very strong moral (I shall not call it religious) sense in him which I take to be one of the most important factors in his make-up.

It is to be noted that he had no formal schooling after he was ten. What else he learned he got as a printer's apprentice plus all he could pick up by indefatigable reading. And this lack of systematic education had clearly much to do with his habits of thought. It had something also to do with his

[2] Smyth, "Writings," IV, 193.

[3] In his letter to Lord Kames of 3 January, 1760. Smyth, "Writings," IV, 6.

[4] On this subject, cf. particularly J. Bennett Nolan, "Benjamin Franklin in Scotland and Ireland, 1759 and 1771." (Philadelphia, 1938.)

[5] Cf. his letter to William Strahan, 7 December, 1762 in "Writings," IV, 182.

[6] "Writings," V, 144. The quotation comes from a letter to Polly Stevenson written from Philadelphia 14 March, 1764, "Writings," IV, 217.

social status in the cultured world of eighteenth-century Philadelphia. He was definitely not of the best Philadelphia families, definitely not received in the most select circles except in the condescending spirit with which the aristocrat accepts the brilliant *parvenu*. He was a craftsman, a self-made fellow, a producer rather than a consumer—a man who depended upon his achievements to exalt his status, not upon his status to magnify his achievements. And he was always more interested in doing things than in speculating about them. What he thought was the by-product of what he did and almost all that he wrote has something of the character of observations made in a laboratory. It will not be forgotten that he was by training as well perhaps as by inclination a newspaper man with a keen nose for the news. But this is probably only another way of saying the same thing. For the newspaper as Franklin conceived it was by way of being a running commentary in the laboratory of developing social phenomena.

His moral sense attaches very definitely to his religious inheritance. His father was a rebel from the orthodox Anglicanism of the English Franklins—one of those non-conformists who met in secret conventicles under Charles II and found it expedient to leave the old country for the more congenial religious atmosphere of the new. He brought with him the later seventeenth-century version of the Puritan tradition, a rigid predestinarianism coupled with a stern Puritan code of morals, but with its adjustments already made to the plans and purposes of the diligent tradesman. Max Weber and Ernst Troeltsch and Richard Tawney have set forth very adequately the nature of these adjustments.[7] The fundamental difficulty which those who held to predestination had to face was the enforcement of a moral code when good behavior could have no possible bearing upon one's eventual fate. If you were elect you were elect—and nothing which you could do would damn you; if you were damned you were

[7] Cf. Max Weber, "Die protestantische Ethik und der Geist des Kapitalismus" (1904–5); Ernst Troeltsch, "Die sozialen Lehren der christlichen Kirchen und Gruppen" (1912); R. H. Tawney, "Religion and the Rise of Capitalism" (1926). The first two of these are available in excellent English translations. Weber particularly has much to say about Franklin.

damned and that was the end o' it. They got round it by insisting that it was the business of the elect to manifest their election, to demonstrate that they were God's chosen by showing forth His praise in their lives. Good works, if not a cause, were a necessary consequence of election. And though no one could know for certain until the last trump who were chosen and who condemned, the major symptom of election was a fine self-confidence revealing itself in upright living. If I am indeed of the elect then I must behave as of the elect. In a sort of way the Puritan created his own salvation by his conviction of it. This looks like a reversion to the Catholic position of justification by works. The fundamental difference was that the Puritans were not seeking salvation by good works, they were revealing salvation by a good life. Confession, repentance, absolution, played no part in their morality. The miraculous element was ruled out. It was not enough to do good sometimes and to win forgiveness for evil doing at other times. The whole pattern of life was in question. Very likely the average fellow was not conscious of the distinction, but he could always fall back upon it to justify at once his belief in predestination and in righteousness of life.

This position explains that preoccupation of the Puritan with his state of grace, that periodical moral accounting which was so characteristic of Franklin himself. Out of it also the Puritan developed the idea of a calling, a vocation, the moral obligation of the Christian to work hard at his profession. Diligence in business became for him an evidence of grace, success in business the surest index of diligence. And so it came to pass, as Tawney puts it, that enlightened self-interest took on the attributes of an ornament to the spirit, and those very acquisitive instincts which had been denounced as vices in the Middle Ages became canonized as virtues.[8]

That there was no inconsistency between piety and prosperity was evident in the case of the Quakers in England and the Pietists in Germany, both of whom were notorious for both. And it is to be noted that the approval of diligence in business was very far from an approval of the mere accumula-

[8] From Tawney's foreword to Parson's translation of Weber's "Die protestantische Ethik," 2.

tion of wealth for wealth's sake. The hoarding of money and its application to worldly display were definitely condemned—idleness was a moral sin as well in the rich as in the poor. John Wesley admitted that "we must exhort all Christians to gain all they can and to save all they can; that is in effect to grow rich." [9] But he added that the good Christian must also give all he can. There must be generous distribution as well as diligent acquisition. The Puritan position, while it condemned idleness and was disposed to condemn poverty as the offspring of idleness, nevertheless encouraged well-directed humanitarian impulses.

It must be observed also that diligence in business was not held to justify sharp practices in business. If lack of diligence, lack of sobriety, lack of thrift are the certain causes of ruination, as Hogarth has pointed out in his contrasted careers of the Industrious and the Idle Apprentice, so too, is dishonesty. You will perhaps recall the lecture which Mr. Wiseman delivered to Mr. Attentive on this subject in Bunyan's "Life and Death of Mr. Badman," "A man must have conscience towards God, charity to his neighbors and . . . moderation in dealing. . . . Let the tradesman consider that there is not that in great gettings and in abundance which the most of men do suppose—for all that a man has over and above what serves for his present necessity and supply serves only to feed the lusts of the eye. . . . Be thou confident that God's eyes are upon they ways, . . . that He marks them, writes them down, and seals them up in a bag against the time to come. . . . Guilt shall go with thee if thou hast got it dishonestly." [10] In Richard Baxter's "Christian Directory" and by John Bunyan the whole moral code of latter day Puritanism is set forth. And Bunyan's "Pilgrim's Progress" was the book Franklin remembered first of all from the readings of his childhood and Bunyan's complete works his first book purchase.[11]

Franklin's code of morals has been described as essentially that of the Puritans with the religious basis left out.[12] Without accepting the statement as sound we may at any rate

[9] Quoted by Weber, op. cit., Parson's trans., 175.
[10] Bunyan, op. cit., G. B. Harrison, ed. (London, 1928), 365–7.
[11] As he himself tells us in his Autobiography, "Writings," I, 238.
[12] Weber, op. cit., Parson's trans., 180.

concede that the Puritan view of doing good irrespective of eternal salvation made possible a Christian ethic without a Christian theology, particularly if we couple with it the prevalent notion that righteous living gave promise of substantial terrestrial rewards. If honesty is the best policy, then honesty along with the other business virtues of diligence, thrift, prudence and sobriety was justified of her children without the need of any divine sanction. Certainly in Franklin's case his morality was self-sustaining. Yet it was undoubtedly the major interest in his life. No man was more given to moralizing, no man more eager to demonstrate the validity of righteousness of life. The book which he never wrote but which most of all he wanted to write was a book on the Art of Virtue in which he intended to show how virtue might be acquired—"To expect people to be good, to be just, to be temperate etc. without showing them how they should become so seems like the ineffectual charity mentioned by the Apostle which consisteth in saying to the hungry, the cold and the naked, Be ye fed, be ye warmed, be ye clothed without showing them how they should get food, fire or clothing." [13]

What then was his religion? The answer to that question is hard to get at with certainty. It is to be remarked in the first place that Franklin never put much store in metaphysical speculations, and he definitely condemned what was generally called in the eighteenth century *enthusiasm*, that is to say ill-regulated religious emotion. He was not therefore prompted by his pragmatical habits of thought to pry very deeply into the sacred mysteries, nor was he in the least impelled by his calm and rational temper to abandon himself to any form of mysticism. With these attributes to start with he early became exposed to the rational philosophy of eighteenth-century England and that exposure made a deeper impression on him than he himself was disposed to admit. Franklin, indeed, to my thinking, is a curious and intricate blending of the pioneer American, the latter-day Puritan and the eighteenth-century rationalist.

While he was yet a boy he had read Locke on the Understanding and the works of at least three of the foremost leaders of the new school of rational theology—Shaftesbury

[13] Franklin to Lord Kames, 3 May, 1760, "Writings," IV, 12–13.

and Clarke and Collins. Before he was twenty he had sat in a London tavern with Bernard Mandeville and listened to his ribald conversation and his cynical exposure of the so-called human virtues.[14] He had even himself composed a pamphlet in which he set forth the view that since God in His infinite wisdom had created all things and set all forces in motion, whatever *was* was right. And he had gone on to draw what seemed to him the inevitable conclusion that since nothing could possibly be wrong in a divinely ordered world "Virtue and vice were empty distinctions." [15] Forty years later when he recalled and recorded his adolescent opinions he declares himself to have been "a thorough Deist." [16] It is not too clear just exactly what kind of Deist he had in mind when he made his comment. There were many such. But certainly the position which they all held in common was very much the position which Franklin had rather crudely stated in what was his first and virtually his only adventure in the realms of metaphysics.

To the Deists and to the eighteenth-century rationalists in general God was, as Paley put it, the great watchmaker, who fashioned the intricate machinery and set it going and then left it to operate according to the laws which he had imposed upon it. There was a grandeur in the conception—but it was a cold, mechanical sort of grandeur. The personal contact of the man with his Maker was gone, the possibility of any

[14] "Writings," I, 243–4, for Shaftesbury, Collins and Mandeville. The sermons which Franklin refers to in his Autobiography, "sermons preached at Boyle's lectures" ("Writings," I, 295), were probably those delivered by Samuel Clarke as Boyle's lecturer in 1704–5 (Sir L. Stephen, "History of English Thought in the Eighteenth Century," I, 120).

[15] "A Dissertation on Liberty and Necessity, Pleasure and Pain," 1725, L. C. Wroth ed. (New York, 1930). The quotation is from Franklin's own summary of this work in his Autobiography ("Writings," I, 296). Smyth deliberately omitted this work from his edition of Franklin's "Writings" on the grounds that "it has no merit" and that Franklin "would have been distressed at its republication." On other grounds Smyth took it upon himself to omit also some of Franklin's more ribald utterances. It is a great pity that what is otherwise the best edition of Franklin's writings should have been emasculated by such impudent exercises of editorial prerogative. As a matter of fact, Franklin is no more Franklin without his philosophic doubts and his occasional indecencies than he would be without his lightning rod.

[16] "Writings," I, 295.

modification in the operation of the great machine in response to the prayers of the worshippers was gone. God retired behind a first cause. He was no longer God the Father, He became the Supreme Being, the Great Contriver, the Prime Mover, the Invisible Hand.[17] And this being so, the problem naturally presented itself to many thoughtful souls as it presented itself to young Franklin—if nature is good then there is no evil in the world, and if there is no evil in the world then good and evil are merely verbal distinctions. This conclusion may have satisfied a cynic like Mandeville, but it did violence to the moral sense of eighteenth-century Englishmen as indeed it did violence to young Franklin's moral sense. A good deal of eighteenth-century thinking was directed to the business of finding some way of reconciling a moral law with a preordained universe. It was in a sort of way the same problem which had faced the Puritans. Different thinkers followed different ways out. The way Franklin himself took was the way that most of his thoughtful contemporaries found satisfactory. "I began to suspect," he wrote, "that the doctrine, though it might be true was not very useful. . . . I grew convinced that truth, sincerity and integrity in dealing between man and man were of the utmost importance to the felicity of life. . . . Revelation had indeed no weight with me as such, but I entertained an opinion that though certain actions might not be bad because they were forbidden by it, or good because it commanded them, yet probably these actions might be forbidden because they were bad for us or commanded because they were beneficial to us."[18] In short he dismissed metaphysical considerations from his mind and accepted a moral law because it was "useful." The fact that it was divinely revealed had little weight with him, the fact that its validity in making for human happiness could be demonstrated was sufficient. He was indeed back to about the position of Richard Baxter, with the religious basis left out.

Now the interesting thing about Franklin's experience is that it had its counterpart in the spiritual history of the outstanding moralists of his time. He was not a freak, he was a

[17] On Deism in general cf. Sir L. Stephen, op. cit., I, passim.

[18] "Writings," I, 296.

type—so typical that he has been cited again and again to illustrate prevalent trends in eighteenth-century moral philosophy. The fact is that both in England and in France Franklin's thoughtful contemporaries were turning away from profitless metaphysical speculations to the practical business of useful and fruitful living. Whether Franklin's own transition was so sudden as he has himself described it is open to question. He was indulging in odd speculations about gods and demigods as late as 1728.[19] When a man writes of his youth after forty years he is apt to foreshorten much in perspective. Certainly Franklin clung resolutely to his gospel of good works and there is almost no evidence in his more mature life of a disposition to explore the sacred mysteries. "I think," he wrote to his father in 1738, "opinions should be judged by their influences and effects, and if a man holds none that tends to make him less virtuous or more virtuous, it may be concluded that he holds none that are dangerous. . . . I think vital religion has always suffered when orthodoxy is more regarded than virtue, and the scriptures assure me that at the last day we shall not be examined what we thought but what we did." [20]

When he was past seventy he set forth the essentials of his faith in a letter to Mme. Brillon,[21] and the famous letter on the subject he wrote to Doctor Stiles at the very end of his life does not differ from it in any essential particular. A God who made the world and governs it by His providence, a God who should be worshipped and served, served best by doing good to our fellows, the immortality of the soul, and a future life, in which vice would be punished and virtue rewarded—these were about all that mattered to him, and every one of them would have been endorsed by the Christian Deists with whom he had played in his youth. There is no essential change. His comments to Doctor Stiles with respect to Jesus of Nazareth familiar as they are will bear repetition: "As to Jesus of Nazareth, . . . I think the system of morals and his religion, as he left it to us, the best that the

[19] Cf. his "Articles of Belief and Acts of Religion," 1728 in "Writings," II, 91ff.

[20] "Writings," II, 215.

[21] "Writings," X, 419.

world ever saw or ever is likely to see, but I apprehend it has received various corrupting changes and I have, with most of the present dissenters in England, some doubts as to his Divinity . . . I see no harm however in its being believed if that belief has the good consequences it probably has of making his doctrine more respected and better obeyed. . . . I have ever let others enjoy their religious sentiments without reflecting on them for those that appeared to me unsupportable and even absurd. All Sects here, and we have a great variety, have experienced may good will in assisting them with subscriptions for building their new places of worship and as I have never opposed any of their doctrines I hope to go out of this world in peace with them all." [22]

The fact is that he attached little importance to theology, and much to righteousness of life. He would have endorsed Alexander Pope's couplet:

> For modes of faith let graceless zealots fight,
> He can't be wrong whose life is in the right.[23]

But he was discreet about making any public utterances on religion, and what he wrote to Stiles he wrote in strict confidence. His constant emphasis is not so much upon the truth of religion as upon the practical advantages of it. He criticized the position of the atheists not on the grounds that their conclusions were false, but that, false or true, they were likely to do more harm than good, that religion was serviceable in restraining ignorant men and women from vice and supporting them in virtue and that the lack of it would be socially more damaging than the fallacies of it.[24]

This is substantially the position of what has been called the Common Sense School of eighteenth-century English thinking, the school to which Franklin's Scottish friends, Lord Kames and David Hartley and Francis Hutcheson and Adam Smith belonged, and to which, in his latter days at least, the most sceptical of them all, David Hume, gave formal

[22] Franklin to Stiles, 9 March, 1790. "Writings," X, 83ff.

[23] Franklin placed an advance order for a new edition of Pope with William Strahan in 1744. "That poet," he wrote, "has many admirers here." "Writings," II, 242, quoted in Van Doren, "Benjamin Franklin," 104.

[24] Cf. on this Franklin's letter to an anonymous correspondent of uncertain date in "Writings," IX, 520ff.

adherence. Franklin once agains conforms pretty closely to contemporary British patterns of thought.

And like these benevolent moralists Franklin came, in later life particularly, to lay the major emphasis upon the esteem attached to a man of virtue. It was, as Carl Becker has remarked, "both sufficient and efficacious, and likely to give one, without any painful searchings of the heart, the assurance of being in a state of social justification or even, if the esteem were general enough, of complete sanctification. I suppose Hume and Franklin when they were in France, for example, must have had this assurance as fully as any saint of the church ever did." [25]

Indeed I think we must all have been struck with the complete confidence with which Franklin faced his latter end. He makes no doubt that he will issue forth again in a new edition revised by the Author. His smugness is akin to the smugness of the latter-day saints, sure of their election. God had abundantly blessed him, the fact of that blessing was the guarantee of larger blessings to come. There were no final harassing doubts, no deathbed repentances. He had made his own salvation, and went forward to enjoy it unperturbed.

Franklin won his first recognition in England as a man of science. We can ignore the affair of the asbestos purse and his youthful contact with Doctor Hans Sloane, one of the great naturalists of early eighteenth-century England. We can ignore also his early desire to meet Sir Isaac Newton, a desire which was never realized—they are only significant as pointing to an interest in scientific matters of all sorts which became stronger and stronger as he grew older.[26] Had he been less of a man of business he would undoubtedly have been more of a man of science, at least he always believed that he would. Certainly his writings which are not political in character and more or less in the line of duty were almost entirely concerned either with scientific phenomena or with moral philosophy. It is difficult to decide which engaged the greater part of his attention, scrutiny of nature or the moral improvement of man. I shall not attempt to appraise his

[25] C. L. Becker, "The Heavenly City of the Eighteenth-Century Philosophers" (1932), 49.

[26] On Sloane and Newton, cf. "Writings," I, 278.

scientific contributions, which ranged over the whole field of physics and biology from stoves and lightning rods to medicine and fertilizers. It is all of a definitely empirical character, and most of it has a definitely social implication. For all his contributions to electricity, his final interest in it took the form of a lightning rod. And he is perhaps better remembered for his Franklin stove than for his more recondite apparatus.

I need not pause to remind you how characteristic this interest in matters scientific was in eighteenth-century Europe, and even for that matter in the more enlightened regions of eighteenth-century America. The obvious proof of it lies right at hand in the reception which Franklin's scientific experiments were accorded. His recognition in the learned world—and this recognition, as you are well aware, took the form of honorary degrees in many of the great European universities and honorary membership in many of the very exclusive European learned societies—was based, first to last, upon his work as a man of science.

Anyone who reads his correspondence is struck, again and again, by his consistent interest in matters scientific. He will interrupt a letter to Lord Kames to tell him how to deal with a smoky chimney. He will fill his letters to his young lady friends with talk about the effects of evaporation upon temperature, he cannot keep it altogether out of his conventionally affectionate but normally quite superficial letters to his very worthy, but very pedestrian, wife. In any case he never really got down to it for any length of time. And his interest in it was always that of a man who was more concerned with making the truth manifest than in monopolizing the credit for its manifestation. Nothing can be more in accord with the true spirit of scholarship than his readiness to share at once any discovery, any observation which seemed likely to stimulate further discovery or further observation. It was his electrical experiments in the 1740's and particularly his experiments with lightning and electricity which first attracted English attention. Indeed they aroused universal attention, won him honorary degrees at both Harvard and Yale in 1753, won him the gold medal of the Royal Society in London the same year and membership in the society three years later. So when he reached London in 1757 on political

business for Pennsylvania he was already a man of international renown.

Undoubtedly the dominating fact in his long stay in England, which with one brief interruption lasted seventeen years, was the developing conflict between England and her American Colonies. It is a long story and an entirely familiar one. The most striking thing about it from the point of view of Franklin as an American is that until the very verge of the Revolution he was very definitely not a rebel, very definitely working his hardest to bring about an accommodation, not a breach. So much so that he laid himself open to the suspicion that he was more English than American in his sympathies. He was even charged with suggesting the Stamp Act.[27] The fundamental issue was of course the right of the English Parliament to levy an internal tax in America. Franklin fought this in theory and in practice. In theory he insisted first of all that Englishmen in America were just as much Englishmen as Englishmen in England, and entitled to the same rights. He conceived of Parliament not as the legislative assembly of the whole Empire, but as the legislative assembly for Great Britain and he placed the colonial assemblies on a parity with it so far as the internal affairs of the Colonies were concerned. The bond of union he insisted was not in the Parliament but in the Crown. He definitely envisaged that dominion status for the American Colonies which turned out in the end to be the true solution of the problem. He was prepared to entertain an alternate solution, to wit, the direct representation of the Colonies in the mother parliament, but he regarded that as running counter to the actual historical development of the situation and no longer achieveable even if practicable. His loyalty to George III remained undiminished almost to the end, though he gradually awakened to the fact that the King was a broken reed to lean upon and that George derived such power as he had from the manipulation of Parliament. What finally led him to accept independence as the only alternative was his realization that, however England at large might feel about it, Parliament as it was then constituted was by and large representative of nothing but the corrupt and self-centered interests of the gang

[27] Van Doren, op. cit., 300.

of politicians who controlled it, politicians who were more interested in lining their purses than in preserving an empire. He had hopes that he might appeal to an enlightened self-interest, and he emphasized again and again the value of an American market to the commercial and the manufacturing interests. But though he did stir up some support for the American position among these interests, the politicians in the end commanded the field. There is very little in his actions or his attitudes in the nature of an appeal to abstract rights, and practically no foreshadowing of the arguments in the Declaration of Independence. His only real assumption was that the Empire should be preserved, and his one objective was to find the best way of preserving it. With the theoretical rights and wrongs, the constitutional issues, he was much less concerned than with the actualities of the situation—the brutal facts of the case. He saw clearly enough that America could not be coerced, but he insisted, as Lord Durham was to insist later in the case of Canada, that Americans were fundamentally loyal and could be depended upon to do their part if they were permitted to do it their own way.[28]

It is rather curious to discover, in view of the fact that he located the root of all evil in the composition of Parliament, that he displayed very little interest in contemporary movements for parliamentary reform. For example, he never saw in John Wilkes anything much more than a licentious, riotous, mischief-loving fellow, and referred to the riots in London in these terms, "Some punishment seems preparing for a people who are ungratefully abusing the best constitution and the best king any nation was ever blessed with." [29] No die-hard English Tory of the time could have put the case against political agitation stronger.

[28] Cf. on this whole subject V. W. Crane's excellent discussion of Franklin's attitude toward the British Empire in "Benjamin Franklin, Englishman and American" (1936), 72ff. I think Professor Crane does not make as much as he might have of Franklin's increasing despair of wringing any reasonable solution of the problem out of Parliament as it was then constituted. Cf. on this subject Franklin's letter to Ross in "Writings," IV, 133, and his better known letter to Galloway in "Writings," VI, 311ff.

[29] Franklin to John Ross, 14 May, 1768, "Writings," V, 133, quoted by Van Doren, op cit., 381.

Later, in his only recorded consideration of parliamentary reform, which shows by the way a rather amazing ignorance of parliamentary history, his recommendations were confined to the abolition of rotten boroughs by purchase. This he set forth in a memorandum to Christopher Wyvill, the assiduous promoter of parliamentary reform among the Whig gentry in general.[30] Franklin seems to have fallen in with Wyvill's own views that the thing chiefly wrong with Parliament was bribery and corruption, that the center of bribery and corruption was in the boroughs and that they should be done away with by buying them out. We cannot regard this proposal as a very penetrating one though it conformed to the current thinking on the subject among the liberal statesmen of both Whig and Tory parties. It came from Franklin after he had ceased to be an Englishman, after America had won her independence. There is very little else in Franklin's writings on the subject and very little indication of his support of, or even of his interest in, a really liberal and democratic program of English parliamentary reform.

And yet we cannot be too sure. One of the few independent glimpses we have of him during his residence in London comes from Josiah Quincy, Jr., a New England lawyer who visited England late in the year 1774.[31] He was the son of one of Franklin's good friends, and Franklin entertained him frequently while he was in London—chiefly it appears at the London Coffee House, in a group which Quincy called a club of friends of liberty. Quincy speaks of meeting there Joseph Priestley, Richard Price, Alderman Oliver, and eight or nine dissenting clergymen.[32] Elsewhere the club is spoken of as the Honest Whigs. We know relatively little about it, and but for the fact that the indefatigable biographer James Boswell visited it on one occasion, we should hardly know of it at all.[33] Quincy's designation seems to suggest

[30] "Writings," IX, 339ff. On Wyvill and his activity in parliamentary reform, cf. G. S. Veitch, "The Genesis of Parliamentary Reform" (1913), 54ff.

[31] Quincy's journal of his life in England is printed in "Memoir of Josiah Quincy Jr. 1744–75," by his son Josiah Quincy, first published in 1825. I have used the second edition (Boston, 1874).

[32] Quincy, op. cit., 204.

[33] Van Doren, op. cit., 402, 421, calls attention to Boswell's contacts with Franklin, citing references in "Private Papers of James Boswell," G. Scott and F. A. Pottle, eds., 18 vols. (1928–34), VII, 193–4, VIII, 111, IX, 40.

that it was concerned with liberty, and certainly there were some radical reformers among its members, Priestley and Price particularly. But we cannot guess. Franklin, in the busy days of war, looked back upon its Thursday evening meetings with particular affection. "I only wonder how it happened," he wrote to Priestley in 1782, "that they and my other friends in England came to be such good creatures in the midst of so perverse a generation." [34] This kind of remembrance somehow does not suggest radical politics.

Indeed Franklin's contacts with English politics seem to have been very largely confined to the business he had in hand. He knew Shelburne and the great Burke and the greater Chatham. There are indications that he contributed his quota to Burke's notable speech on Conciliation and to Chatham's arguments in support of the American position in the House of Lords. But he probably felt it indiscreet to participate in purely domestic issues. It was characteristic of his pragmatical habits that he was not much inclined to talk about things which he was not in a position to do anything about.

His other contacts in England were mostly with a varied company. Among his closest friends he numbered a prosperous London printer, a Welsh bishop, two prominent dissenters and two distinguished physicians. He once went to Ireland with one of Charles Lamb's benchers of the Inner Temple.[35] He visited at the country house of the notorious Sir Francis Dashwood, leader of the still more notorious Monks of Medmenham—though elevated to the peerage as Baron Le Despenser and gone respectable when Franklin knew him. Of them all he got most pleasure out of the Scottish philosophers but most instruction out of the dissenters. Probably

[34] "Writings," VIII, 453.

[35] I refer to Richard Jackson, of whom Lamb writes in his "The Old Benchers of the Inner Temple," "Jackson,—the omniscient Jackson he was called—had the reputation of possessing more multifarious knowledge than any man of his time." "Essays of Elia," Augustine Birrell, ed., 2 vols. (1902), I, 181. On Jackson's adventures with Franklin in Ireland, cf. Mr. Nolan's admirable account (op. cit., 123ff). I think Mr. Nolan is wrong (p. 3) in speaking of Jackson as "Two Penny Jackson." Lamb himself distinguished clearly between Jackson and Twopenny who, according to Birrell, was not a bencher but a stock broker who had chambers in the Temple. (Lamb, op. cit., I, 181n.).

it was Priestley and Price who made a Unitarian out of him. It is rather curious to find none of the London wits or the London men of letters among his friends. He met Edward Gibbon, the historian, once by accident, and is accredited with a *bon mot* on that occasion which is almost too good to be true.[36] He met David Garrick at least once at a house party, and he met the indefatigable Boswell. To Boswell we owe one of the few intimate pictures we have of Franklin's London life, the picture of Sir John Pringle and Franklin over a chess board—Pringle very sour, Franklin "all jollity and pleasantry." "A prime contrast," Boswell observed, "acid and alkali."[37] It is to be regretted that he never met Dr. Samuel Johnson, though Franklin might have disappointed us if they had met. He was never much given to acrimonious controversy, and certainly Johnson and he were poles apart on the American issue. His most congenial intimates were Scotsmen, the most notable of them David Hume the philosopher, Lord Kames the advocate and William Robertson the historian. It is not surprising that he found himself more at home in their company than in any other. He had himself a Scottish mind, direct, clear, matter of fact. Later he confessed that the six weeks he spent in Scotland were "six weeks of the densest happiness I have met with in any part of my life." Adam Smith he certainly knew, though how well is a matter of controversy. In general it is to be observed that Franklin's English social contacts were normal friendly ones based upon community of tastes and a common interest in common problems. His life in England lacked the glamor of his later adventures in France. He never became the fashion in England, and had no temptation to play to the galleries which later led him sometimes to make himself slightly ridiculous. There is a certain exotic quality about

[36] Van Doren (op. cit., 577) transmits the story from Horace Walpole. It is to the effect that Franklin, stopping by chance at the same inn with Gibbon, requested the pleasure of his company—to which Gibbon answered that, with all due respect to Franklin as a man and as a philosopher, he could have no commerce with a rebel. Franklin answered, with all due respect to a distinguished historian, that when Gibbon came to write of the decline and fall of the British Empire, Franklin would be happy to furnish him with material.

[37] Van Doren, op. cit., 402.

his whole French experience. In England he definitely belonged.

The problematical character of Franklin's connection with Adam Smith raises the issue as to the relation between Smith's economic philosophy and Franklin's.[38] Time does not serve to investigate the matter in detail. Certainly Franklin was a disciple of the laissez-faire philosophy. But equally certainly Laissez-faire had received wide endorsement both in America and in England before ever Smith set pen to paper. We may surmise that Franklin arrived at his position through a somewhat different channel from Smith—not as the natural derivation from the rational philosophy of the times but as a practical protest against a system of economic control which at the moment was bearing with particular heaviness upon America. To Franklin Laissez-faire was born of the Navigation Acts. It was to him a specific remedy for a specific ailment. But very likely he welcomed the classical expression of the principle in universal terms. Here again as in so many instances Franklin's thinking seems to have run *pari passu* with progressive English economic thought.

What I hope I have succeeded in demonstrating is that Franklin in every department of his thought and action was profoundly influenced by his English inheritance and by his English connections. He was to be sure an American, brought up in the freer air of America and mercifully delivered from the inhibitions of class and station and tradition which cramped the style of so many of his contemporaries in the Old World. He was delivered also from the inhibitions of a conventional education whose crystallized patterns of thought often turn out to be more of a liability than an asset in a rapidly changing world. But he was nevertheless a typical eighteenth-century figure and he moved easily and naturally in an eighteenth-century world. There was nothing abnormal about him—the difference between him and his fellows was a difference of degree and not of kind. Indeed, one of his major characteristics was his adaptability to all sorts of situations, his ability to get on well with all sorts and conditions of men. His

[38] Franklin's economic views in general and his relations with Smith in particular are well considered in Lewis J. Carey, "Franklin's Economic Views" (1928), particularly 107ff.

mind was singularly alert, but it was an eighteenth-century mind and in the long run the positions which he reached in his thought and action were recognizable eighteenth-century positions. Getting on in the world was his *métier* and though he comprehended in his definition of getting on definite humanitarian purposes, get on he did, in the American world, in the English world and in the French world. He would have got on in any world. He accepted the universe as it was, and his theories about it, scientific, political, economic, religious, were little more for him than working hypotheses, to which he gave no absolute allegiance and which he was prepared to modify or to abandon when they no longer served the needs of concrete situations.

He clearly belonged with those whom Becker gathered together in the Heavenly City of the eighteenth-century philosophers. Like them he accepted the world as a good world, his place in it as a good place. He looked like them for the resurrection of the dead and the life of the world to come. And yet one feels that he would have been acutely unhappy in any celestial paradise where all the crooked ways were made straight and all the awkward questions answered.

Obstacles Beset Transmission Line Builders in India.—ROGER A. BLACK. (*Electric Light and Power*, Vol. 19, No. 11.) When American engineers design a transmission line they are confronted with several problems such as providing adequate lightning protection, securing a safe margin of mechanical strength, taking care of differences of elevation, building tower foundations in soil which will not support a heavy load, and erecting special towers for river crossing and other long spans. In India, the engineers have many of these same problems but in addition have numerous others to plague them. For example, the temperature during the hot weather season varies between 80 and 150 degrees Fahrenheit. It is impossible to work between 11 A.M. and 3 P.M. because the materials and tools get too hot to handle. At the beginning of the monsoon, construction is hampered by the heavy rains, precipitation in excess of two inches per hour being quite common. Materials have to be transported by ox cart in some parts of India, and further delays are occasioned by the several Hindu and Mohammedan religious festivals. Another difficulty is the encountering of sacred trees which are worshipped for Mythological reasons by both Hindus and Mohammedans. Neither the line crews nor local inhabitants will cut down sacred trees because of the dire consequences they fear would ensue. This problem is generally overcome by offering a sacrifice of goats to each tree, the number of goats being commensurate with the sacredness of the tree. Trouble is also caused by dacoits (bands of armed robbers), who raid the camps at night, slit the tents and take clothes, camp stores and tools. To combat this trouble, a light is usually kept burning in the camps and chowkidars (watchmen) are kept on duty all night. When pin-type lines are built, consideration must be given to the bird fault problem. Vultures, cranes and other large birds find transmission lines ideal places on which to perch. V-shaped crossarms are employed as a preventative. All of these obstacles were encountered by the Government of the United Provinces during the construction of its Ganges Canal Scheme. This vast project was undertaken to irrigate 4,000,000 acres of fertile land in the old states of Oudh and Agra and to furnish electrical energy for domestic and industrial use in that area.

R. H. O.

MANAGEMENT'S ROLE IN DEFENSE.*

BY

WILLIAM L. BATT,

Director of Materials, Office of Production Management, Washington, D. C.

This is an appropriate time and place to remind ourselves of what American industry is trying to do; to do to fulfill the pledge that this nation has made to world democracy; and to indicate something of the tremendous proportions of the industrial job that must be done. For, as the nation becomes more deeply immersed in the defense effort it becomes increasingly difficult for the individual to comprehend and appreciate what is taking place under his own eyes.

You will have read that by the end of the present year more than 17 billions of dollars will have been paid out in the defense effort (including lend-lease expenditures and what the Reconstruction Finance Corporation is spending for armament plants). But do we realize what 17 billions of dollars is? What it represents in terms of materials? In human effort? Yet that is the sum only so far spent by our government . . . and, definitely, the end is not yet. The practical task of turning this money into munitions rests largely with those executives of American industry known as "the managers," the men who must solve the knotty management and engineering problems occurring in day-to-day operation of a manufacturing organization—men whose problems are the nation's problems and whose victories over their problems, are victories over the enemies of democracy.

OUR INDUSTRIAL BACKGROUND.

Now, to obtain a real understanding of what management is doing we must go back a little, so that our perspective will be broad enough to give a full view of the compass of the task. If we review our war effort of 1917 we see that our

* Address delivered on the occasion of the award of the Vermilye Medal to William S. Knudsen, December 1st, 1941.

preparations were late as compared to those of the other powers. If we go back to the beginning of the present war, it is only too evident that our preparations were late again.

We are not traditionally one of the world's great munitions makers. While it is true that during the first World War we produced armaments in vast quantity, we returned as quickly as possible when the war was over to the manufacture of peacetime goods.

We are known to the world as makers of automobiles, radios, telephones and washing machines. Ours has been a consumers' economy, and we know how to make such goods better than any nation on earth. But now skill in peacetime pursuits has lost its importance. What we must do (and are doing) is to change the course of the mighty American stream of consumers' goods. Few of us, even those in management, appreciate the size of our own industrial system, for it is ramified beyond the comprehension of any one individual and its power is so great that we have never known how to open the floodgates all the way. To change all this is to attempt a feat of truly staggering proportions. But that is what is going on today.

Taylor.

There once lived, here in Philadelphia, a man named Frederick Winslow Taylor who had a theory and proved it. His theory was that by the application of certain principles of work, men could always learn to produce goods more efficiently and more abundantly, and that by doing so they could live better. Taylor's beliefs were bitterly opposed when he first enunciated them, but time proved him right and now Taylor's science of work is accepted throughout the world. Indeed, when we were in Russia only a few weeks ago, we saw the factories of that beleaguered country using methods originally developed by Taylor in this very state of Pennsylvania many years ago.

We must not forget the name of Taylor because the present world struggle is going to be decided by the countries that can best apply his principles of dynamic efficiency.

German Preparations.

The United States in 1917 learned many things about the preparations for war. Industry of the present generation must regard with respect the production statistics of those years. But Germany studied our effort of 1917, and during the 1930's began to improve upon it. By the time war broke out in September, 1939, the Reich had developed an intricate network of war industries that operated with an unbelievably perfect degree of coördination. It was a system of decentralized manufacturing with emphasis on small plants that were scattered throughout the countryside—the kind of productive system with a high degree of resiliency. Germany learned the first principle of industrial mobilization, namely, that the whole effort proceeds with the speed of the slowest producer: that the secret of mass munitions production is a perfect system of coördinated deliveries.

Subcontracting.

In contrast with this, the English and American industrial systems at the time the war began were highly centralized. In England the ever-present danger of aerial bombardment proved a constant threat to the self-contained manufacturing plants and required the breaking up of large plants into small scattered units.

We are beginning now to see that the only answer to "all out production" is to resort to "farming out" or subcontracting, the system that has worked so efficiently for the Germans. Only in that way can all the "muscle" of the sprawling industrial giant that is America, be brought into play.

But this farming-out system has its problems. As I have tried to indicate, they are principally those of coördination, and the more farming out that is done, the more magnified becomes the problem of coördination. Consider, for example, the manufacturer of the 37 mm. tank gun. This is a typical example of the subcontracting process. The prime contractor in this case is a maker of printing type and similar printers materials (Anerican Type Founders, Inc.) who had no experience in making guns and had no machines to make them. The gun itself consists of 10 principal parts which are being

manufactured by 37 different companies scattered from Philadelphia to Davenport, Iowa.

It is obvious that operations in these different plants must proceed at a uniform pace, for if the delivery of one of these parts is delayed then it prevents the assembly of the whole weapon. Now, magnify this case by literally thousands of others and you will have some idea of what is going on in our war industries today.

AREAS OF GREATEST DIFFICULTY.

Now, going back again to the first World War years, what were the principal sources of delay? We are told by men who have studied that experience, that the delays of that war effort could be traced to the following causes: (1) imperfections in liaison between government and industrial personnel; (2) lack of standardization in the design of equipment; (3) irregular "tooling up" operations among companies working on the same product; (4) lack of coördination in delivery of finished parts; (5) inefficiency among some plant managements.

Quality of Management.

It is the last mentioned of these factors that is probably the most important of all because, unfortunately, industry does not enjoy a uniform, high standard of management. Let us look for a moment at the immediate background of management. For many years prior to 1940–1941, management was schooled in the ways of conservatism as contrasted to the philosophy of dynamic expansion and production that had been our background of a few decades ago. Indeed, a large part of our present-day younger executive personnel received its training in the deflationary era of the '30's.

But, now, almost overnight, the demand on management has changed. Our problem is no longer that of intensively developing markets and producing just the proper amount of goods at the lowest possible cost to fill the markets' expected demand. Instead, we are asked to apply our most dynamic techniques to the mass production of *all* the goods we possibly can, in the shortest possible time and with cost a very secondary concern.

Undoubtedly, at the beginning of the defense program there was inertia; there was fear of overexpansion. Many business men *did* want business as usual and defense production only if necessary. There was fear of losing peacetime markets, etc. But I think today much of this reluctance is gone. The feeling is growing that defense must come first—*civilian* manufacture only if necessary.

On the whole the efficiency of American industry, I sincerely believe, is far beyond that of other nations of the world. I have referred to Taylor, the father of scientific management, and his heritage to America, yet one management authority believes that the total production of war material could be increased at least 20 per cent. by raising the management methods of most plants to the standards of the best plants. Think what this would mean! Think what effect it would have on the course of the war if our output of war materials could be increased to such an extent, at no cost of machines or man-power.

Manpower.

The second great area of difficulty for management has been in personnel, the shortages of trained executives and skilled workers necessary for expansion. Many companies during the depression, because of lack of volume, had to drop their training work, as "extra expense," and the problem now is to apply "forced draft" techniques to the training of "green" people. The defense program continues to call for a greater supply of skilled men than exists, and this demand shows no signs of diminishing.

Meanwhile, the demand for workers has greatly increased the bargaining power of labor and has provided an opportunity for unions to press for wider organization and higher wages. The immaturity of our unions and the cleavage in the labor movement, in which two great labor organizations compete against each other, have contributed immeasurably to the delay of our defense effort.

However, while one must naturally be concerned with strikes, I don't believe the elimination of strikes alone will provide the management and labor unity that ultimately will be necessary for this defense program. Mere discipline is not

enough, because the efficiency that it produces is only a simulation of real efficiency which springs, as Woodrow Wilson said, from "the spontaneous coöperation of a free people."

It is our job in the final analysis to create and develop voluntary coöperation between management and labor, for no matter how powerful a combination of money, machines and materials a nation's industry may have, this is a dead and sterile thing without a team of willing, thinking and articulate people to guide it.

Materials.

One of my associates has expressed the problem of materials so well that I want to quote it:

"Another area of serious difficulty is the procurement of materials. Estimates of direct defense requirements in almost all important materials will be greater in 1942 than in 1941. By direct defense requirements I mean those that are being bought directly as such by the Army and Navy or are going into products which the Army and Navy are buying. (We must expect increased lend-lease requirements.)

Indirect defense and essential civilian requirements, such as the steel for machine tools and industrial machinery, the materials needed to build new plants, the requirements for maintenance and repairs and operating supplies, and the minimum amounts needed to keep our civilian economy going, will, I believe, increase.

On the other hand, at some point, the rate of production of defense products may level out and this will stabilize the demand for materials. Part of the present demand is probably going into excess inventories. Increased production of many materials is under way. But I doubt that these factors will, in most cases, offset the increase in defense requirements. (I feel sure that it will be the policy of our government to apply the maximum amount of our materials and productive capacity to defense.)

On top of all the defense requirements, there is, of course, the demand for other civilian uses. This demand is not being satisfied now. In view of our increasing national income it will presumably be larger in 1942 than in 1941. Therefore, I cannot believe that even if our estimates of defense require-

ments are too high, even if all projected increases in production are realized (even if there is no interference with imports), we can anticipate any substantial relief from the shortage of critical materials until the emergency is over. There may be some relief in some materials, but I think we must plan in terms of continuing shortages.

The individual company, no matter in what line of activity it is engaged, must reckon with the materials problem. A year ago the words 'shortages' and 'priorities' meant little to the average individual. But now they represent a grim reality. The conclusion is inescapable that the lot of companies whose objectives do not complement the defense program will become more difficult. Business must prepare for increasing scarcity of many materials and for more and more restrictions on particular uses. Every company should analyze its business to determine how it will be hit by these developments. Concerns that feel their products are non-essential and are likely to be prohibited must try to shift their production to more essential products."

OPERATING PROBLEMS.

And what of the multitude of operating problems that must be solved by manufacturing organizations? Much of the excellent work being done by management has been beclouded by the publicity that has attended recurring strikes and labor difficulties.

I am afraid that most of the public has been given the impression that management's principal concern today is its labor problem. The headlines might lead one to believe that most of management's time is spent in discussions with unions and that nearly every company is either in the middle of a strike or in the process of settling one.

I do not need to remind you that industry is constituted very much like our population of householders, and for every-one whose name gets into the headlines there are thousands more who quietly go about their business, competently discharging their responsibilities. Every defense order that is placed, no matter how small, must be scheduled, engineered, planned, priced, must go through the manufacturing process. Machines must be maintained, jobs must be reorganized, new

factories must be planned and erected, materials must be scheduled and procured. That is the everyday work of management. There are too great numbers of men and management who are peacefully working together day after day.

Multiple-shift operation has presented a whole new set of problems to American management, which in most industries has been accustomed only to single-shift operation. The problems of supervision, scheduling and inventory control have become magnified. The priorities problem has become so difficult that many companies have had to set up separate priority departments. And the scarcity of materials has set whole corps of technicians to work in single companies on the problem of conserving materials.

I mention these things merely to suggest to you some of the new problems that confront management today.

Up until a few weeks ago we heard criticisms about the delay in our defense effort. I think only recently has the public begun to realize that tangible results in the way of immediately useful munitions have been accomplished. Certainly some of the earlier criticisms were premature, but I think, with the background I have sketched for you, that we could not have expected an immediate flood of war materials from a country so thoroughly geared to peacetime production. I happen to think that the change could have been brought about more quickly, but the important thing *now* is that the transition is being accomplished. American war strength will not be able to show itself in the spiked-lightning form that Germany's showed itself in 1939; rather will it come in the form of slow, steady pressure until its effect is felt throughout the world. Then a mighty, inexorable stream of weapons will be turned against the enemies of democracy, a stream larger than you and I can now imagine.

I want to quote a paragraph from one of the American Management Association reports which can fitly end these random remarks on management:

"History has a favorite trick that it persists in playing again and again. It rarely permits the full import of great events to be appreciated by those living at the time the events occur. It saves the effect for generations that come after those living have passed away. History is again playing that

trick. We know that there is a storm over the world and that it is blasting familiar landmarks of the earth into new forms; we know the storm is taking a fearful toll of men's lives and that it is costing much in terms of what men have created and hold priceless. But changes more subtle and more profound are taking place. It is almost impossible for us to estimate the full reverberations of the present world struggle. Only this we know: That, whoever wins the war, the world in which contemporary leaders have arisen is passing. Our children will know a different world."

As we look into that future, you and I, like all thinking men and women, have forebodings. Who can escape them? Perhaps we Americans have not yet fully learned the price of freedom.

But what we are doing now we must do—and, having done it, will take our compensation in the hope that the future will be brighter than if we had done nothing.

That, it seems to me, is the philosophy of this man of great simplicity whom the Franklin Institute is honoring tonight. Day after day, he meets these problems of management squarely, unequivocally, without drama, because he knows the job must be done and because he has been delegated to do it.

His compensation is summed up in an old Danish saga that I have heard him quote:

"Fortune dies
Friends may die
I myself shall die
But reputation never dies
For him who has fairly gained it."

Here's Mud.—(*Industrial Bulletin of Arthur D. Little, Inc.*, No. 174.) Oil wells now go as far below the surface of the earth as most airplanes fly above it. The oil well depth record, held by a well in Kern County, California, is now 15,004 feet in depth. Until 1928 the depth record was 7586 feet, and in 1930, 10,000 feet was yet unattained. Today there are throughout the world more than 700 wells over 10,000 feet deep. Many technological improvements have made these depths possible, and one of the greatest of these is mud. In the rotary drilling of an oil well, a highly specialized quality of mud slurry is pumped continuously down the drill pipe to the cutting bit at the bottom of the drill hole. In returning to the surface through the annular space between the drill pipe and the hole wall (which may or may not be lined, depending upon the strata through which the well is being sunk), the slurry carries with it the cuttings from the action of the bit on the whole bottom. The slurry also plasters the walls of the hole where it is not lined with pipe, thus keeping out the water leaks and partially balancing by its own weight the pressure of inward leaks. To fulfill all these functions, the mud must have the density, viscosity, and wall building qualities required by the wall characteristics of the individual hole. Furthermore, the qualities must be flexible to meet changing circumstances, and, of course, the cost must be at a minimum. The muds are generally made from clays obtained from as near the drilling site as possible. If necessary, these are treated chemically to get a slurry of proper viscosity, or they are weighted with minerals such as iron oxide or finely ground barytes to obtain the proper density. Bentonite clays are sometimes added for their lubricating value and to increase the carrying capacity by increasing the gel strength of the slurry. Chemical treatment includes addition of tetrasodium pyrophosphate, a detergent used in dishwashing soaps. This compound aids in controlling the acidity of the slurry, which affects the stability and gel strength. Quebracho or chestnut extract may be added to control dispersion of particles, and substances such as starch, Irish moss, or alginates (extracted from seaweeds) are used to maintain plastering properties at high temperatures encountered for underground.

R. H. O.

STABILITY OF OSCILLATIONS IN SYSTEMS OBEYING MATHIEU'S EQUATION.

BY

JOHN GRIST BRAINERD,

Moore School of Electrical Engineering, University of Pennsylvania.

ABSTRACT.

Numerous relatively simple physical systems give rise under appropriate circumstances to oscillations which obey the equation $y'' + \epsilon(1 + k \cos t)y = 0$ (Mathieu's equation). These oscillations may be either stable, periodic, or unstable, depending upon parameters of the physical system as expressed by the parameters ϵ and k in the basic equation. It has been customary to distinguish between the stable and unstable states by diagrams of the type of Fig. 1, from which it is possible to tell whether a given set of values of the parameters ϵ, k will yield a stable or unstable solution. In this paper are given curves which not only present this information, but in addition give for an important part of the stable state the values of the characteristic exponent μ. The solution of the equation $y'' + \epsilon(1 + k \cos t)y = 0$ depends to a large extent on this exponent, and the availability of values of μ should greatly facilitate the practical application of the equation.

Consider a simple series electric circuit containing a fixed resistance r, a fixed inductance L, and a capacitance C which varies with time τ, so that $C_0/C = 1 + K \cos \omega_a \tau$ where C_0, K, and ω_a are positive constants, and $K < 1$ to avoid having $C < 0$. The circuit is a linear varying-parameter system, which might be realized by properly shaping the plates of the capacitor and having them rotated at constant angular velocity ω_a by a motor.[1, 2] The charge q at any time τ is given by

$$L \frac{d^2q}{d\tau^2} + r \frac{dq}{d\tau} + \frac{1 + K \cos \omega_a \tau}{C_0} q = 0. \qquad (1)$$

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[1] W. L. Barrow, D. B. Smith and F. W. Baumann, "A Further Study of Oscillatory Circuits Having Periodically Varying Parameters," JOUR. OF THE FRANKLIN INSTITUTE, 221, no. 3, March, 1936, p. 403, and no. 4, April, 1936, p. 509. Contain references to previous work. Some (few) values of μ may be derived from the results of these two papers and previous papers by Barrow.

[2] F. J. Maginniss, "Sinusoidal Variation of a Parameter in a Single Series Circuit," *Proc. I. R. E.*, 29, no. 1, Jan., 1941, p. 25.

If the resistance r be neglected, (1) becomes

$$\frac{d^2y}{dt^2} + \epsilon(1 + k \cos t)y = 0, \tag{2}$$

where $t = \omega_a\tau$ and $\epsilon = 1/\omega_a^2 LC_0$, and y has been written for q and k for K.

If on the other hand r cannot be neglected, then

$$q = ye^{-\alpha t},$$

where

$$\alpha = r/2\omega_a L$$

and y is given by (2) with $\epsilon = (1 - r^2C_0/4L)/\omega_a^2 LC_0$ and $k = K/(1 - r^2C_0/4L)$. Thus q again depends on the solution of (2).

Equation (2) occurs in studies of modulation,[3, 4] in electric machinery problems, in circuit problems such as the one outlined above, and in many non-electrical problems of technical importance.[5, 6] It is thus desirable for practical purposes to have the solution of (2) at hand for various ϵ, k pairs. At the present time such solutions are not available, but a gradual approach to their attainment is being made.[7] The purpose of this paper is to present curves which will facilitate the obtaining of these solutions by giving values of the characteristic exponent μ, defined below. These curves serve both to delimit the stable and unstable states and to give μ for a wide range of the stable state.

For background the following outline of theory is offered:

Equation (2) is a linear equation of second order, with varying coefficient. For any given ϵ, k, let g be y for the initial conditions $y(0) = 1$, $y'(0) = 0$ and h be y for the initial

[3] J. R. Carson, "Notes on the Theory of Modulation," *Proc. I. R. E.*, **10**, no. 1, Jan., 1932, p. 57.

[4] J. G. Brainerd, "Note on Modulation," *Proc. I. R. E.*, **28**, no. 3, March, 1940, p. 136.

[5] B. Van der Pol and M. J. O. Strutt, "On the Stability of the Solutions of Mathieu's Equation," *Phil. Mag.*, **5**, no. 27, Jan., 1928, p. 18. (Gives numerous references to applications of Mathieu's equation.)

[6] W. G. Bickley, "Notes on Mathieu Functions—I," *Phil. Mag.*, **30**, Oct., 1940, p. 312, and references there cited.

[7] J. G. Brainerd and C. N. Weygandt, "Solutions of Mathieu's Equation—I," *Phil. Mag.*, **30**, no. 203, December, 1940, p. 458, and references there cited.

conditions $y(0) = 0$, $y'(0) = 1$. Then the general solution of (2) can be written

$$y = Ag + Bh, \tag{3}$$

where A and B are constants.

It can be shown [7] that

$$g = u_1 \cos \mu t - u_2 \sin \mu t = U \cos (\mu t + \theta_U), \tag{4}$$

$$H = u_1 \sin \mu t + u_2 \cos \mu t = U \sin (\mu t + \theta_U), \tag{5}$$

where u_1 and u_2 are periodic functions of t with period 2π

$$H \equiv (1 - b^2)^{1/2} h / h(2\pi), \tag{6}$$

$$b = g(2\pi) = h'(2\pi) = \cos 2\pi\mu, \tag{7}$$

$$U = (u_1^2 + u_2^2)^{1/2} \tag{8}$$

and

$$\theta_U = \tan^{-1}(u_1/u_2). \tag{9}$$

Equations (4) and (5) show that the g and H solutions, which by (3) fix y, are simple combinations of the periodic functions u_1 and u_2 (period 2π), $\sin \mu t$ and $\cos \mu t$. The u_1 and u_2 can be represented by Fourier series, and often approximated by a few terms,[3] so that only knowledge of μ is required to approximate the solution. When $b < 1$, μ is real according to equation (7), and the solution is said to be stable. When $b = 1$, the solution is periodic of period 2π and is called a Mathieu function. These particular solutions, for which μ is zero, an integer, or an integer divided by 2, have been studied extensively.[8] When $b > 1$, the solution is unstable.[9] In this case μ is purely imaginary, and it is convenient to write g and H thus:

$$g = e^{j\mu t}\phi_1 + e^{-j\mu t}\phi_2, \tag{10}$$

$$-H = j(e^{j\mu t}\phi_1 - e^{-j\mu t}\phi_2), \tag{11}$$

where $j \equiv \sqrt{-1}$ and ϕ_1 and ϕ_2 are periodic functions of t, period 2π, which are simply related to the u_1 and u_2 used in (4) and (5).

[8] Professor P. M. Morse has prepared an extensive table (unpublished) of the periodic functions, which extends the work of Ince [10] and Goldstein.[11]

[9] In the first paper to which reference is made in footnote 1, the term "unstable" is adversely criticized and not used. It is, however, quite generally used elsewhere.

If now curves along which $b = 1$ are plotted in the ϵ, k plane, these curves separate stable and unstable states. For a limited range Fig. 1 shows such a diagram, of a type which has

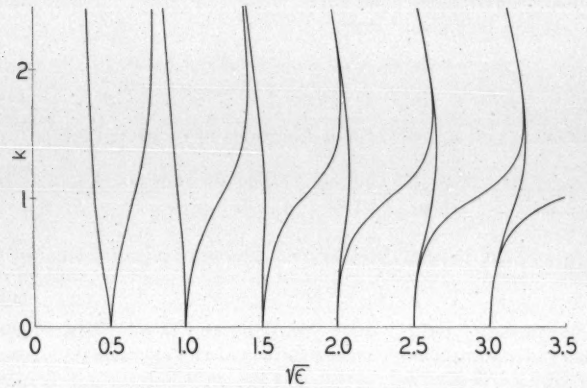


FIG. 1. Stable and Unstable Regions. Any ϵ, k pair falling in a region between two adjacent curves which start from different points on the $k = 0$ axis corresponds to a stable solution, in any other region to an unstable solution, on a curve to a periodic solution.

been extensively used in applications of equation (2). These curves originated in the calculations of Ince[10] and of Goldstein,[11] and are pictured in different form by Strutt.[12]

Equation (7):

$$g(2\pi) = h'(2\pi) = b = \cos 2\pi\mu \tag{7}$$

makes use of the recently discovered fact that $g(2\pi) = h'(2\pi)$, and hence that a family of curves of b versus ϵ for various k's will give μ. Fig. 2 shows such a family of curves (derived

[10] E. L. Ince, "Researches into the Characteristic Numbers of the Mathieu Equation," *Proc. Royal Soc. of Edin.*, **46**, 1925, p. 20 and p. 316; "Tables of Elliptic Cylinder Functions," **52**, 1932, p. 355.

[11] S. Goldstein, "Mathieu Functions," *Trans. Cam. Phil. Soc.*, **33**, 1927, p. 303.

[12] M. J. O. Strutt, "Lamesche, Mathieusche undverwandte Funktionen, etc.," Berlin, 1932. (Contains extensive bibliography.)

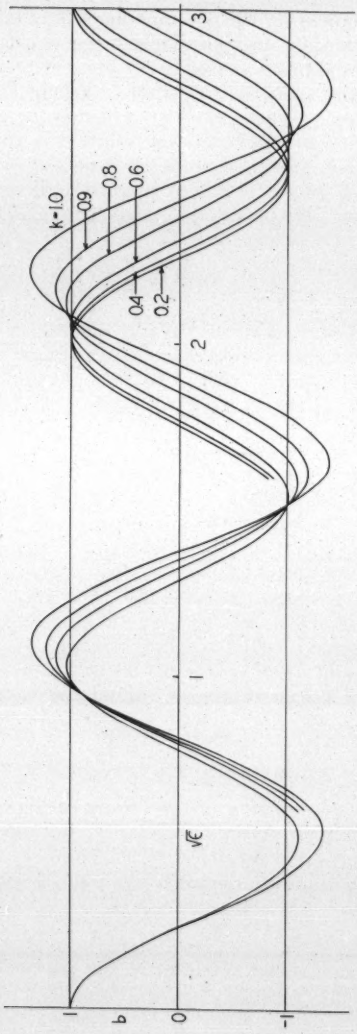


FIG. 2. Family of curves of b versus $\sqrt{\epsilon}$ with k as the parameter. The characteristic exponent μ is given by the curves since $\cos 2\pi\mu = b$. Where $b = 1$, the solution of equation (2) is periodic and the locus of points $b = 1$, plotted in the k, $\sqrt{\epsilon}$ plane, gives Fig. 1. For $b < 1$, the solution is stable; for $b > 1$, unstable. For the sake of clarity portions of some curves have been omitted.

from results obtained on the Moore School differential analyzer) which gives μ for an appreciable range of ϵ, k. Wherever a curve goes above $b = 1$ or below $b = -1$, μ is purely imaginary and the solution is unstable. Where $b = 1$, the solution is periodic. Where $|b| < 1$, which is the case for a major part of the curves shown, the solution is stable; μ is real and is readily obtained from the curves. The near-periodicity of the curves is noteworthy, as well as the fact that when $k = 0$, the characteristic exponent μ is not zero, since in this case (2) reduces to

$$y'' + \epsilon y = 0, \tag{12}$$

whence

$$g = \cos(\sqrt{\epsilon}t) \tag{13}$$

and

$$H = \sin(\sqrt{\epsilon}t) \tag{14}$$

and g, H, and y have the period $2\pi/\sqrt{\epsilon}$ whereas u_1 and u_2 have the period 2π. Since

$$u_1 = H \sin \mu t + g \cos \mu t \tag{15}$$

and

$$u_2 = H \cos \mu t - g \sin \mu t \tag{16}$$

it follows that for $k = 0$,

$$u_1 = \cos(\sqrt{\epsilon} - \mu)t, \tag{17}$$

$$u_2 = \sin(\sqrt{\epsilon} - \mu)t, \tag{18}$$

and that for u_1 and u_2 to have a period of 2π, $\sqrt{\epsilon} - \mu = N$ where N is any integer or zero. Taking the case $N = 0$,

$$\mu = \sqrt{\epsilon},$$

$$b = \cos(2\pi\mu) = \cos(2\pi\sqrt{\epsilon}), \tag{19}$$

which gives the $k = 0$ curve of the family of Fig. 2. (The $k = 0$ curve has been omitted for clarity, but the $k = 0.2$ curve approximates it closely.)

There is a relationship[7] between the g and h solutions of (2):

$$gh' - hg' = 1, \tag{20}$$

which holds for all values of t and of the parameters ϵ, k.

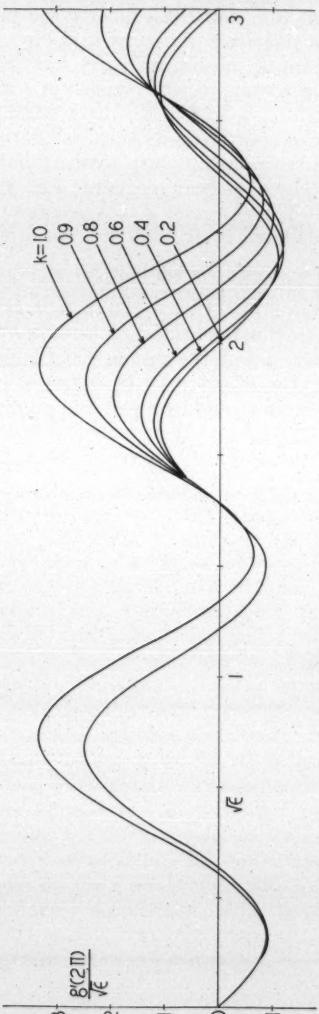


FIG. 3. Family of curves of $g'(2\pi)/\sqrt{\epsilon}$ versus $\sqrt{\epsilon}$ with k as the parameter. From the curves of Fig. 2 and this group, the values of g, g', h, and h' at $t = 2\pi$ may be obtained. For the sake of clarity portions of some curves have been omitted.

At $t = 2\pi$, $g = h' = b$, and consequently the product $-hg' = 1 - b^2$ is derivable from the curves of Fig. 2. If $g'(2\pi)$ and $h(2\pi)$ are known, as well as $g(2\pi) = h'(2\pi) = b$, it is possible to obtain for appreciable ranges of t about 2π the g and h solutions of (2), and hence the general solution, by means of approximation methods such as the Kutta-Runge method.[13] Since the requisite data were available from the work for Fig. 2, they have been plotted in Fig. 3, which gives $g'(2\pi)/\sqrt{\epsilon}$ vs. $\sqrt{\epsilon}$. The choice of $g'(2\pi)/\sqrt{\epsilon}$ rather than $g'(2\pi)$ as ordinate was dictated by the fact that for $k = 0$,

$$g'/\sqrt{\epsilon} = \sin(\sqrt{\epsilon}t),$$

as can be seen from (13). Hence $g'(2\pi)/\sqrt{\epsilon} = \sin(2\pi\sqrt{\epsilon})$ and is a simple periodic function of $\sqrt{\epsilon}$. The case $k = 0$ has not been shown on Fig. 3, but the case $k = 0.2$ approximates it. From Fig. 2 $g(2\pi) = h'(2\pi)$ may be obtained, from Fig. 3 $g'(2\pi)$ can be determined, and by equation (20) $h(2\pi)$ can then be found, hence g and h and their first derivatives at $t = 2\pi$ are given by the two families of curves shown in Figs. 2 and 3.

[13] C. Runge and H. Konig, "Numerisches Rechnen," Berlin, 1924, p. 311.

A NEW THEORY OF COMBUSTION IN DIESEL ENGINES.

BY

MAX G. FIEDLER,

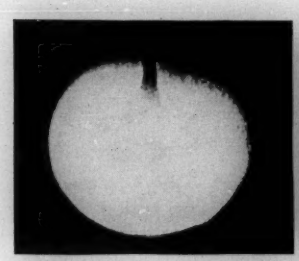
Vice-President, Fiedler-Sellers Corporation.

(*Continued from January issue.*)

What were the industry's engineers doing? They were building Diesel engines, and the general conception was that they ought to know all about it. I went to many lectures—one in Philadelphia—hoping to learn something. The lecturer usually started out and said, "Now, we have a Diesel engine of great economy, and so forth—they are a little heavy, but I'll show you what they do." And he would show a picture of some kind of pre-combustion chamber, and another and still another, and by the time he was through he had shown some 20 different chambers, and I was on the verge of saying, "Why do we need all these chambers? Why does everybody do something different—what is wrong with the situation? None of these chambers is really any good."

I went to one such lecture where I hoped to get the answer, and the answer was this: Everything that is good for a Diesel engine is bad for a gasoline engine, and everything that is good for a gasoline engine is bad for a Diesel engine. I felt very depressed. When the discussion came up one engineer would say, you need high compression—make it as high as possible. The next would say you only need 400 lbs. The next would say, "I get away with 120 lbs." Or one would say, "We need long duration"; another that we need short duration, etc., and I was so distressed because I felt that friends of mine, engineers, would go back and having those discussions in mind would go to the industry and necessarily unsuccessfully spend more money and time. So in one of these discussions I got up and said, "Gentlemen, I have to say something that you will not like, but anything you have said here is contrary to my experience."

This was taken rather as a joke; so I tried to give another lead. I said, "Gentlemen, what do these irregular pressure lines mean?"



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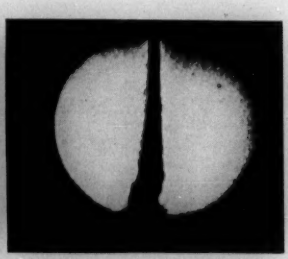

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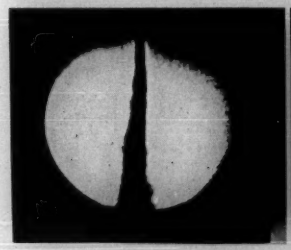

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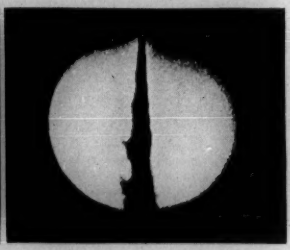

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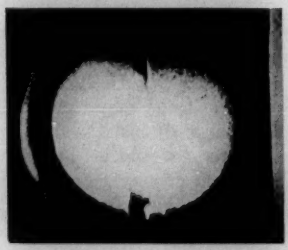
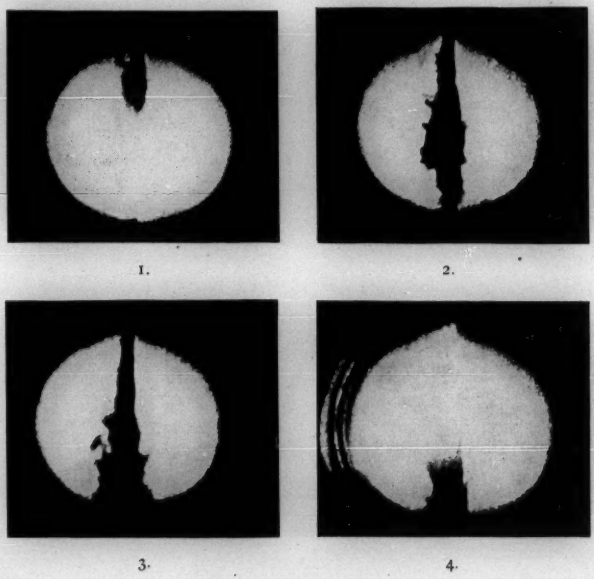


5.

Single spray small orifice.

The answer was, "Oh, those are indicator vibrations; if Mr. Fiedler would put a weight on the end of the indicator arm, these vibrations disappear."

So, you see, the engineers, at that time, were sitting on the indicator, making the indicator say what they wanted it to say, what they wanted to see; making the indicator show



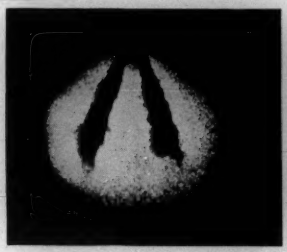
1. 2. 3. 4.

Single spray large orifice.

them what they wanted to see; not what the indicator was trying to show them.

I have a film here that I want to show you. It was taken by the N.A.C.A. I saw it, and the peculiar thing was that what the engineers wanted me to see, I didn't see at all. In fact, it wasn't of any importance—but what I saw which was of extreme importance they didn't pay any attention to.

If I showed the film as it was taken, it would lose its effect, so I have rearranged it. You will first see appearing on the screen a white disk, representing the combustion chamber. Then you will see the discharge of a single orifice into that chamber, under high compression into extremely high turbulent air. You will see a single spray discharged



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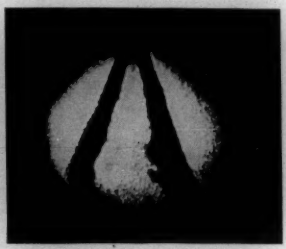

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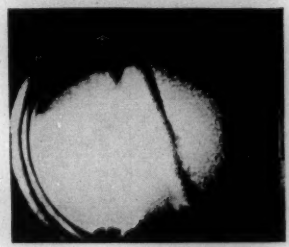


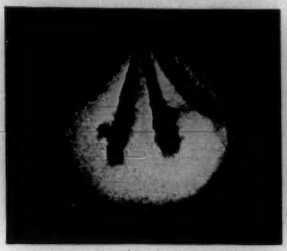
3.

Double spray.

out of a small hole, then out of a larger hole, and then out of two and four holes, and so forth. I would like you to watch that spray very, very carefully, because it gives a clue to what happens, and to what was apparently overlooked for years. I would like to have that film now.

. . . The film followed during which Mr. Fiedler made the following remarks . . .

You see that the spray penetrates the whole chamber and that the turbulent air apparently has no effect on the spray formation itself. You also see that there are no indications of the hydrocarbon igniting in spite of the fact that the air temperature is way above the flash point of the injected oil. This condition holds true for every nozzle, and



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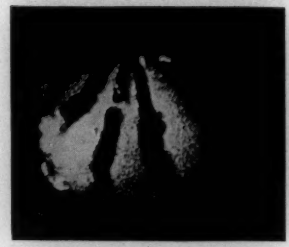


3.

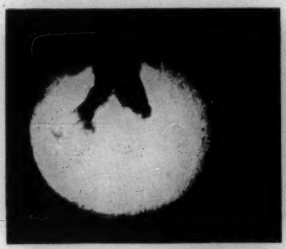
Four spray holes.

although the size of the orifice (referring to the first and second series of single spray hole injections) has an effect on the characteristic of the spray, it does not seem to have any effect on the ignition point.

Most interesting is the film of the 4-hole discharge. You will see that somewhere in the chamber with no relation to the actual spray, white spots appear indicating a part re-

action. This part reaction will give us another clue which we will analyze later.

Even the last series, which represents a slot valve, and in which case you know the fuel spray is very finely divided and very thin so it can be easily reached by air, shows that



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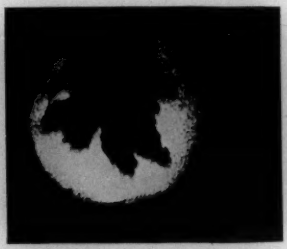

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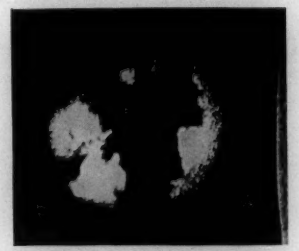


3.

Slot nozzle.

the temperature and surrounding air has no effect on the spray, and does not induce combustion.

. . . End of film. . .

Now Gentlemen—what you have seen there—I don't know if you realize it or not; but that spells the doom of the Diesel cycle, and I will explain why.

When Dr. Diesel had his first idea, the fundamental efficiency of his cycle depended on the possibility of adding

heat at maximum temperatures and pressures at the rate of conversion, meaning at the rate at which the heat would be converted into power. This meant that he was going to

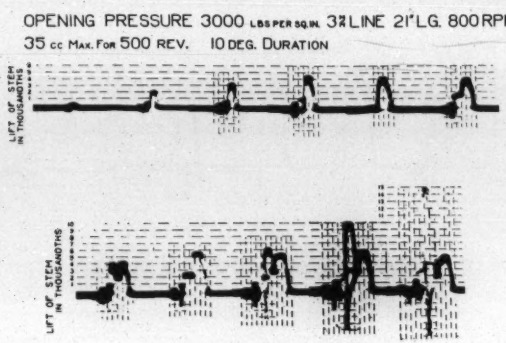

OPENING PRESSURE 3000 LBS PER SQ.IN. 3% LINE 21" LG. 800 RPM
35 cc MAX. FOR 500 REV. 10 DEG. DURATION
LIFT OF STEM IN THOUSANDTHS
LIFT OF STEM IN THOUSANDTHS

FIG. 27.

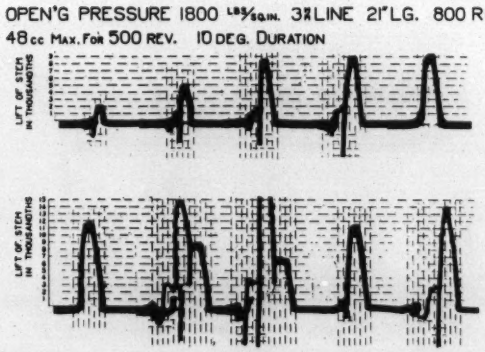

OPEN'G PRESSURE 1800 LBS/SQ.IN. 3% LINE 21" LG. 800 RPM
48 cc MAX. FOR 500 REV. 10 DEG. DURATION
LIFT OF STEM IN THOUSANDTHS
LIFT OF STEM IN THOUSANDTHS

FIG. 28.

control combustion by the rate of admission of the combustible matter into the combustion chamber. Nobody at that time—they might have doubted everything else Dr. Diesel said—doubted that if you have air at temperatures of 2,000 or 3,000

degrees, as he was playing with, that anything that burns, injected into this air would immediately ignite and cause

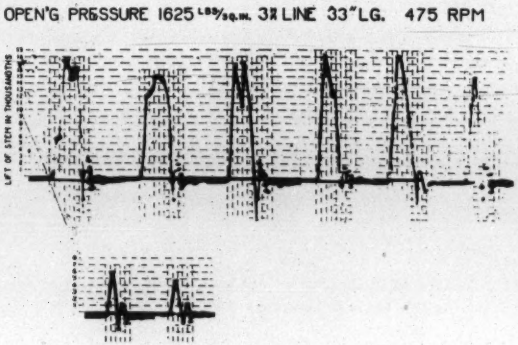


FIG. 29.

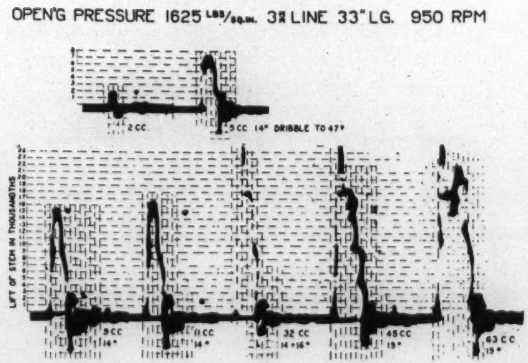


FIG. 30.

combustion, and it is almost fantastic that this vital error in Dr. Diesel's plans was overlooked.

The realization that combustion could not be initiated by introducing combustible material into high temperature air

was very depressing to me. I would not have had any hope that there would be a solid injection engine that could have any permanence at that time if it had not been that occasionally we would see cards that looked presentable. Why, we didn't know. We already knew that we had to do everything radically different from accepted practice to get indications of good combustion. For instance, use 4 or 5 mm. fuel lines as

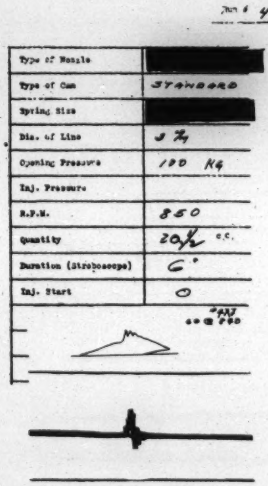


FIG. 31.

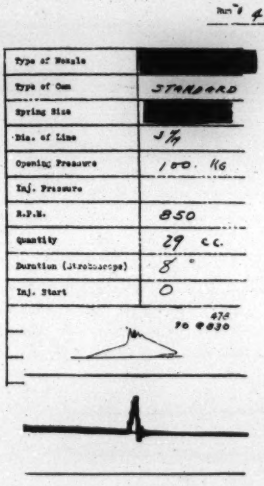


FIG. 32.

against the recommended ones of 1 or 2 mm. inside diameter; use low injection pressure, and heavy springs; tremendously out of proportion, heavy springs on the valves. But we didn't know why.

So we decided to follow these very meager leads and built an apparatus which consisted of a box; in this box was a stroboscope, and on top of the box was an optical indicator. We photographed the stem movement of the valve itself while we were looking at the spray that was produced by the

nozzle. I will show you now some of these photographs that we took of valve stem movements (Figs. 27, 28, 29 and 30).

These are the records of this procedure. Figures 31 to 35 show various loads at approximately the same speed. There was noticeable detonation although not violent enough to be destructive. Figures 36 to 39 show the same records with a different valve combination. The performance of the engine

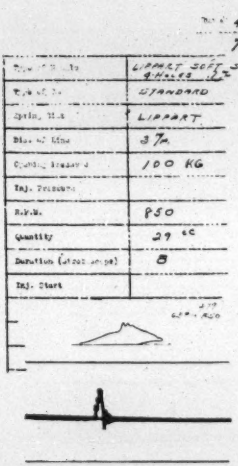


FIG. 33.

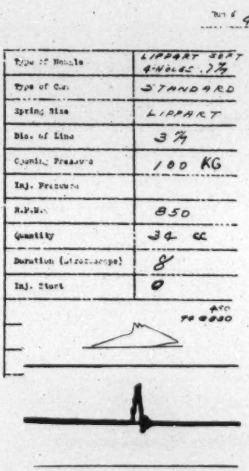


FIG. 34.

was better and any noticeable knock or detonation had disappeared. We arrived at this valve combination by looking at the spray formation and out of a whole group of valves, this particular valve gave us a definitley different characteristic. This induced us to try this combination and the diagrams show the results.

Now let us see what we learned. We learned first of all we had to have instantaneous injection and had to try and avoid too much atomization. That apparently was poison. We had to see that the spray did not hit any hot spots in the

cylinder. In fact the spray should not come close to any hot centers.

Then we started thinking that something must happen to the fuel itself when we injected it; and it just so happened that I met a very outstanding chemist and I asked the following question. "I am puzzled. I don't know what it is

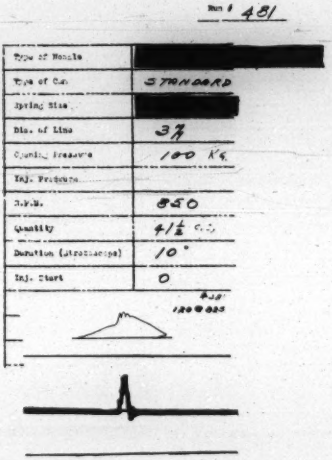


FIG. 35.

all about. Anything we find in our investigation is absolutely contrary to the standard conception, but it works."

He took out a piece of paper and said, "When you get detonation, do you get these zig-zag lines?"

I said, "Yes. Why do you ask?"

He said, "I would imagine if you had a hydrogen explosion that that is the kind of card you would get."

And then we went home and took out a handbook and looked up under the page "Combustion" and were slightly baffled. It was right in front of our eyes. It said if you take hydrocarbon and mix it with air and bring it up to certain

temperatures, you get complete combustion, but if you expose the hydrocarbon to temperatures without the proper air being present, then the hydrocarbon will dissociate into free hydrogen, marsh gas and carbon. The carbon comes out of the exhaust and the hydrogen after it has formed the correct auto-ignition mixture, will cause detonation.

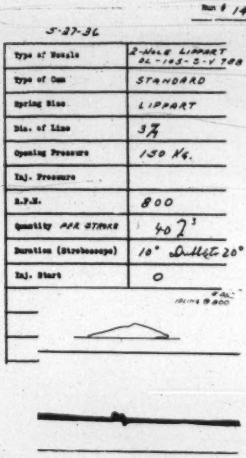


FIG. 36.

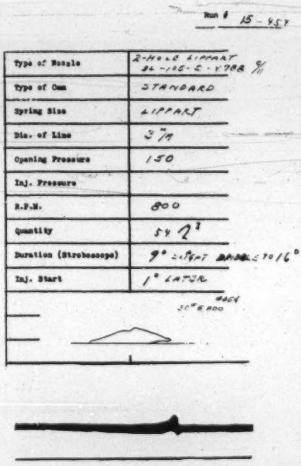


FIG. 37.

Now how does this fit into the picture? Let us take the standard Diesel engine. You will see that we poked the fuel into the combustion chamber in the form of a stick. Now we have all held a stick over a fire when we were kids—and this is what happens. The stick starts to discolor; then gradually fumes start bleeding off. These fumes will not catch fire unless you hold the stick farther away, where there is oxygen available. Then they will puff off. If you keep it up long enough your stick will be in your hands in the form of a stick of carbon.

That is exactly what we have been doing in the case of the Diesel engine—we have been sticking a piece of hydrocarbon, finely atomized, into air of approximately 1,000 degrees, and have forgotten all about our experience with gasoline engines.

Some of you might remember when you had to carry a little squirt can around to start your gasoline motor. You

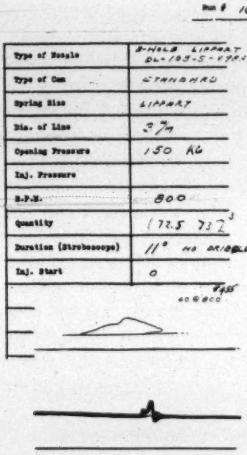


FIG. 38.

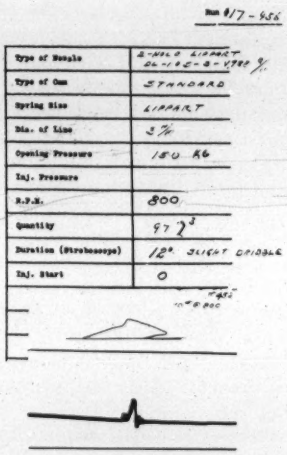


FIG. 39.

remember two squirts were just enough. If you made it two and a half the motor would not start. Why? Because it did not make the correct mixture in the cylinder. Today we have a starter. We push on the starter, pull the choke, and if that doesn't help we get somebody to push us.

In the Diesel engine we have an identical combustion reaction—we can't expect any combustion until we establish an auto-ignition mixture, because we don't have even a spark, and if we don't establish an auto-ignition mixture before the hydrocarbon reaches its critical temperature we bleed off free hydrogen and get the so-called Diesel knock. That explana-

tion seems simple now that we know the answer and since we know that it is correct. We know now how to make the engine work in that way, but imagine the damage that such a simple, wrong analysis has done to the industry.

Take the Diesel equipment industry. Years ago a man with tremendous foresight knew there would be a field for Diesel engines and started building injection equipment. His firm, and ultimately other firms on a license basis, built this equipment mechanically perfect but to the specifications of the industry and with the wrong conception of Diesel combustion. What happened? Some manufacturer of gasoline engines said, "I think the Diesel is here to stay—I ought to get busy building Diesel engines. Well, I can build everything but the injection equipment—I'll buy it from this firm and profit by its experience."

The manufacturer would put the injection equipment on the engine and the performance would be terrible. The result was he would blame the injection equipment manufacturer. But the injection equipment manufacturer had given the industry what it demanded. That the analysis was wrong was not his fault. If the Diesel engineer had given him the right analysis he would have manufactured the other equipment. But this mistake has in effect cost the industry millions of dollars because as in this one case, as in many others, the engine that was supplied with that standard injection equipment automatically could not give satisfactory performance.

I will now show you a slide of our nozzle development (Fig. 40). It shows several phases of the nozzle development which we had to go through before we reached the final stage.

No. 1—is a standard valve and corresponding indicator card. No. 2—is the first modification. This modification already gave good cards at low speed. No. 3—is the next modification, after which we started building our own valves. Finally we came to No. 7 which seems to be the best that we can do today. Now to give you an idea how disastrous this whole situation has been, I would like to show you another slide. I don't know if you'll recognize it.

Fig. 41. In 1930 an outstanding firm announced, "We have the Diesel aircraft engine—we have an engine that will revolutionize air transportation." And among the publications was this—(Diagram)—I have saved it—they stated. "We have developed the aviation Diesel cycle." The only trouble with this diagram is that there are only two possible points which are correct, the highest and the lowest, and the engineer connected these points to suit himself. The tragedy lies in the fact that millions were spent by this firm and en-

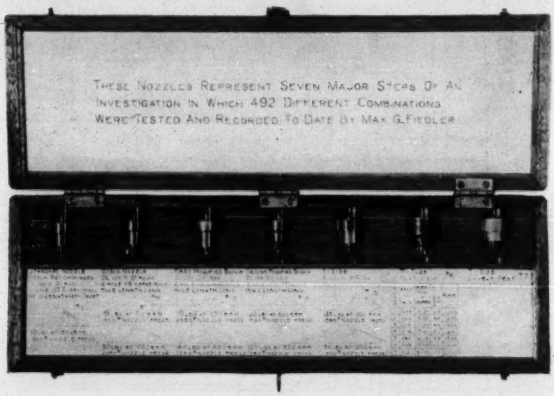

THESE NOZZLES REPRESENT SEVEN MAJOR STEPS OF AN
INVESTIGATION IN WHICH 492 DIFFERENT COMBINATIONS
WERE TESTED AND RECORDED TO DATE BY MAX G. FIEDLER

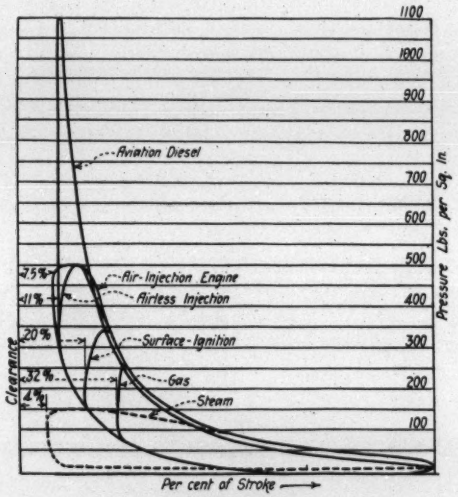
FIG. 40.

gines actually built on that cycle, and construction patents taken out which would permit the engine to stand up under these terrific stresses. It was not surprising that this engine was a failure. You cannot hold an engine together under combustion conditions that are accompanied by as violent detonations as in this specific case.

Now what is the value of all this information to the industry? We can say this much today—we can produce decent combustion. We know what it should look like on an indicator card and we know what causes it. We don't know everything: we have a lot to learn. It will take some

time before we can be fool-proof, if ever, in our diagnosis. But let's keep the following conditions in mind.

Fig. 42. This one card is close to what the aviation cycle would look like if the engineer had drawn the correct diagram. The card on the right, superimposed, represents good detonation-free combustion.



Practical engine cycles

FIG. 41.

I showed these cards once before, and I was told they were faked. That is why the originals are reproduced on top. It might be interesting to know that they were both taken at the same engine speed, namely, 1,500 revolutions. The one card with violent pressure variations and strong detonation represents no load with a conventional injection equipment and nozzle. The other card represents 90 lbs. b.m.e.p. after only the injection equipment was changed.

Now I don't want you to say, "Send a nozzle and the engine will be perfect." The engine has to be analyzed—the

combustion chamber has to be right, and you have to do some experimenting with the valves to locate the spray properly in the cylinder and avoid hitting any surfaces at all because if you hit surfaces you get vaporization of the fuel, and that vapor exposed to high temperatures will cause dissociation and the resultant Diesel knock.

If what I told you tonight means anything at all, I don't want you to feel that I take credit alone. I want to say

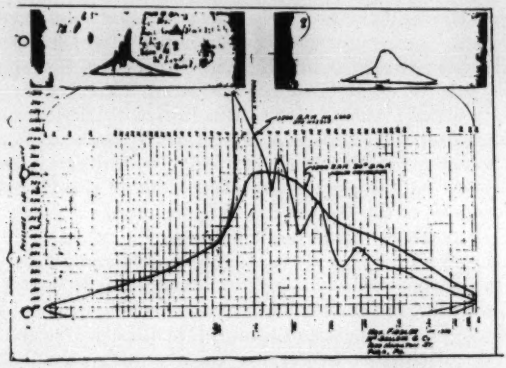


FIG. 42.

that a large amount of the credit goes to those who, at moments when I was almost despairing, believed in the sincerity of my work and due to their friendship gave me the courage to continue.

I thank you.

CHAIRMAN WETHERILL: Ladies and Gentlemen, the meeting is now open for discussion. Is there any discussion?

MR. H. FISCHER: I have been in the Diesel game since 1906. I was with a company which up to the time of the world war built about one million horsepower. The company during the war developed an air injection submarine engine of about 420 mm. stroke. The combustion of these air injection engines is the most perfect I have yet seen. You get an indicator card like that (drawing on board). I couldn't see

anything wrong with that combustion—in fact I have not been able to find any engine able to produce this combustion. We atomized and mixed the fuel properly so the instant it left the nozzle it burned. In fact the nozzle opened here (describing from diagram) between 2 and 3 degrees top center, etc.

Of course people have the conception that in an open chamber engine we have to inject very fine, very finely atomized and I agree with Mr. Fiedler that this conception is wrong. His idea is quite right because you set up a high temperature and the fuel will dissociate as he has shown.

Now, I am representing a company which produces equally good cards—I can't duplicate them every time, maybe, but I have to congratulate the author for his excellent work, to be able to produce an indicator card with that very slow pressure rise in that open chamber type of engine.

CHAIRMAN WETHERILL: Is there any other discussion? If not the Chair recognizes Professor Sloan of the Mechanical Laboratories of the University of Pennsylvania.

PROFESSOR SLOAN: I don't know why I am asked to discuss this, because there is very little more I can add to what Mr. Fiedler has said.

He didn't draw your attention to something which possibly has some effect on the analysis of this last speaker's card here. He is dealing with a two-cycle engine running possibly 2,000 r.p.m. whereas the other gentleman speaks of a 4-cycle engine with half the number of injections per minute.

As I say, this man has given you a rather unusual type of paper this evening. I wouldn't call it a paper because he did not read it. But it is unusual in this respect. The majority of scientific discussions cover some one little phase of experimental work over a period of possibly anywhere from, in our field, maybe only three months, because we are constantly asked to write papers. He, however, tries to tell you in one hour what I know he has been working on over ten years, and it is remarkable and unusual in that respect.

He left out a lot of things—a lot of things he might have said. The development of his engine first, his first conception of it, and I will thoroughly endorse what he said about the little three cylinder gasoline engine that you saw on the screen. I was amused when he first brought it to our laboratory—

I was amused when I heard it was coming to the laboratory, because we had at that time so many of the terrible crank case, two-cycle engines coming to the laboratory that I was thoroughly discouraged and had no desire to test the engine. When I first saw the engine I wasn't so sure, and when I saw it run, I was convinced that it was the best I had ever seen—and I haven't seen anything like it since.

When he started to work with the engine which he said was a failure—that is the one where he comes to use a mixture in a separate cylinder, and forces it over to the power cylinder—the first idea of course was to use gasoline. When he decided that that was the thing, that that particular construction could be used as the basis of high speed Diesel engines, I was myself staggered with the idea. I could not possibly conceive, in view of what we knew ten years ago about injection, what we were going to do about injecting oil into the cylinder and burn it properly at the speeds of 2,000 or 3,000 r.p.m. You, in the game, know, in 1928 there was no such animal on the market and nobody was dreaming of making 2,000 injections per minute into an engine. When I pointed it out to Mr. Fiedler that the tough part of the whole job is going to be the injection problem, he agreed at the time, but decided we would have to let that take care of itself when we got to it, hoping, I suppose, possibly, that somebody might have an injection system by the time he was ready for it.

Some time before that engine was made, I had the honor of having a chance to discuss it with a representative of one of the largest organizations in the country. This man is supposedly a high speed engine man, and while his reputation had been acquired in the gasoline engine field, he nevertheless had been charged with the duty of watching the developments in the Diesel field. I went thoroughly over the drawing—the engine had not been built at the time—and after a night's discussion he finally told me about 4:00 o'clock in the morning that he was sorry to see anyone spend so much effort on such an engine, because he was of the opinion it wouldn't even run.

I bring that to your attention for the following reason: I am surprised that the man, even though not a Diesel expert, should have overlooked the most important part of the whole thing. That was not the mechanical construction of the

engine nor the method of supercharging, but the difficulty of obtaining an injection and combustion in such a cylinder head, such a chamber, at such terrific speeds. But it never entered his mind at all. He just had an idea because of the peculiarity of construction, it wouldn't run. I have often been sorry he couldn't have been standing beside us a while ago, and am sorry that we couldn't corral him about the "engine that wouldn't run."

Now, about this remarkable paper—not remarkable, but unusual. He hasn't told you all the grief, by any means. There is always one headache after another in the development of such a thing. But he has been in this work a great many years and I move, Mr. Chairman, that we congratulate him and thank him. (The motion was seconded and carried.)

CHAIRMAN WETHERILL: Mr. Fiedler, you have our profound thanks.

The meeting stands adjourned.

. . . After adjournment the meeting was again called to order by the Chairman . . .

CHAIRMAN WETHERILL: Mr. Berlyn, from Canada, has a few remarks he would like to make in discussion.

MR. BERLYN: There are one or two points on which I would like to have Mr. Fiedler's views. I understand that he attributed the cracking, the distillation, the dissociation of the hydrocarbon fuel to its being injected into a volume of highly heated air, and that would imply that in order to avoid that process of dissociation it would be an advantage if the air were not so hot, or possibly a reduction in temperature of the air charge could be arrived at by reduced ratio or some change in the conventional designs, both of which alternatives might result in reduction of the thermal efficiency of the engine. If you increase, for example, the potentialities for heat flow from the air charge, you are throwing perfectly good heat away that you have paid for in fuel oil.

Now another point, and that concerns cold starting. Now for some reason or other the people who buy Diesel engines set store by the attribute of cold starting. I am not so sure, myself, that it amounts to much because there are a number of admirable aids to starting which are marketed as proprietary articles, but certain designs of engines with pre-combustion

chambers have been criticized that they are not cold starters really, and are fitted with a gasoline starting engine, and the cooling jackets of the starting engine are hooked up with the cooling jackets of the main engine. It has been said, in fact, that the function of a starting engine is not so much starting engine as a stove. It seems to me to be going a long way to start an engine that way.

But it seems to me if you are trying to avoid dissociation of the fuel into component hydrogen and methane and carbon, that the measures you will have to adopt would mitigate against the cold starting and possibly against the best thermal efficiency. I personally have found, for example, that an easy start can often be made on a reducted engine by increasing the fuel valve opening pressure. Anything, in fact, which will make a finer spray, which I believe is the condition which Mr. Fiedler would avoid because it is a condition conducive to dissociation of the fuel.

Now I would like to know if Mr. Fiedler is hopeful of retaining all the virtues of good cold starting and high thermal efficiency, which have been attributed to open combustion chamber Diesels of large size.

MR. FIEDLER: I think those were two very intelligent questions, and I thank you for asking them, because it brings out certain points I could not bring up before.

It is quite true that we try to operate at the highest possible compression ratios, of course in all of these kinds of problems we have to compromise. What we want to do, and what we have to do, to get decent combustion is to inject the hydrocarbon instantaneously. That is what we try to do. We want to inject it so it is in liquid form at the lowest temperature range possible so that it has a lot of time before reaching the cracking point. It should go in in liquid form in small drops, as small as possible although there is a limit to that. We know if you raise your venturi speed in a carbureter beyond a certain point, the atomization of the gasoline does not help the efficiency any more.

As far as the chamber itself goes, the ideal condition would be a chamber with a non-conductor at the surface backed up by a high conductor to prevent heat accumulation. We do not want hot surfaces, which are hotter than the air tempera-

ture at the time of injection. That is the important point. We don't want to raise the air temperature through hot spots in the chamber itself, and the cooler we can keep the chamber, the higher we can go with the compression ratio.

There is only one thing of importance; that is that the right auto-ignition mixture is formed before the hydro-carbon reaches the critical temperature. Now that, of course, ties in with the starting. I think it is correct that the salesmen invented that cold starting idea. As far as I know, there is no cold starting Diesel engine. The engine that carries the highest compression ratio is the Junkers—the cranking speed and starting compression are slightly over 360, and if the temperature gets down to 10 degrees above zero, that engine won't start if you crank your arm off. If you realize that, I would say a cold starting engine would be one starting at 10 degrees below zero, and you have to use engineering brains to overcome that condition. You should choose the compression for the best efficiency of the engine, and then find means for easy starting—because there is no cold starting Diesel.

I think that answers the two questions.

DR. MAGDEBURGER: I would like to rise in the defense of a mechanical explanation of the jigger lines on the card. I grant you you may be right, but why did the jigger lines appear on the indicator card of an air compressor (drawing) like this, for example—where they are evidently inertia effects of the valves, and for similar reasons they are evidently or quite possibly may be inertia effects on the masses of the indicator. That is Number One.

I want to ask you also for an explanation of why violent explosions would occur in starting, on the air injection engine, presumably all the air injection engines. The explanation we have was because (drawing) frequently the piston chamber is made like this, and a leaky valve accumulates quite a product up here. How does that fit in with your idea?

MR. FIEDLER: As you say, when you start a Diesel up you accumulate fuel by faulty injection or something. Now what happens? You have exactly what you don't want—you have fuel which has accumulated on some surfaces, you expose

this to compression heat over a long time, during the whole compression stroke, and the result is you get vapor.

DR. MAGDEBURGER: Off the flat surface?

MR. FIEDLER: Sure, off the flat surface, and that is the vapor that causes the engine to knock.

DR. MAGDEBURGER: Violent explosion?

MR. FIEDLER: I say "knock"—of course, it might knock off the cylinder head. But that is a typical accumulation—you can produce it any time. That is the reason Dr. Diesel's engine was destroyed. He had that condition in his engine and the moment the vapor bled off enough hydrogen it caused the explosion.

DR. MAGDEBURGER: And what do you think of that inertia effect of the masses on the sudden pressure?

MR. FIEDLER: You mean what causes the jiggle? The mechanical effect on the structure or the inertia effect?

DR. MAGDEBURGER: The valve must be accelerated, when it is here it has to go down considerably before it is lifted (Referring to previous diagram).

MR. FIEDLER: This is the indicator card.

DR. MAGDEBURGER: And the same way when it is compressing.

MR. FIEDLER: Now don't you think that the air column might do that, due to the closing of the valves?

MEMBER: Yes, but it shows that same effect of acceleration of masses may exist, which doesn't require your explanation of explosion.

MR. FIEDLER: Yes, but at the time where there is a change let us say in the air column, but not in the combustion.

DR. MAGDEBURGER: That isn't a combustion chamber.

MR. FIEDLER: I know, but the air flutters, and that causes an air motion and the indicator registers. Isn't that correct?

DR. MAGDEBURGER: But the valves themselves flutter. Why wouldn't it be so at high speed?

MR. FIEDLER: We don't have anything that flutters. I want to show you something you might not have realized on the cards. You might have seen that the card looked like this (drawing) and coming down here, and you get a jiggle down here. We thought at first these little jiggles were due to the indicator. Then we checked it and found this point matched

the point at which the supercharging port is uncovered. There is a vapor accumulation in the pocket and that causes the indicator to register in that manner. If an indicator can register 40 lbs. difference in pressure at that point, it is going to be pretty accurate at high pressures.

Here's another thing. It doesn't make any difference if the jiggle lines are correct or not as long as they correspond to a condition which destroys the engine, and the indicator shows us this other characteristic when the engine runs smooth (Diagram). That is all we want to know—we don't care about the absolute indication of the instrument any more.

CHAIRMAN WETHERILL: May I ask this: If you take a pressure diagram on an Otto cycle engine (drawing diagram) with a knocking fuel, you get this wiggly line. Now if you put tetra-ethyl lead in the fuel you get that (describing)—all right, why is that? That is caused by the valves, isn't it?

MR. FIEDLER: That is not caused by the valves. Let's take (drawing) on "L-head" motor. Here are the valves. You buy your car and she doesn't knock. Then after a while she starts knocking and you go to the garage man and he says you have carbon in the cylinder and you will have to have the carbon removed.

"What does the carbon do?" you say. And the answer you get from an automotive engineer is, "It raises the compression." And they tell you that is due to accumulation of carbon in here. That is absolutely ridiculous because the amount of carbon is so small it won't have any effect on the compression pressure, but what it does do is that during the intake stroke your carbon deposit being here—the gas is drawn in during the intake stroke and part of the spongy carbon soaks it up. On the compression stroke that gas is given off as vapor, and if you look at photographs of combustion under these conditions you will find that it starts here (near the spark plug), and then suddenly you get a white flash over here (at the other side of the chamber). This last reaction causes the detonation. What happens if you add tetra-ethyl lead? We know now that we can take a hydrocarbon apart and put it together again in some other arrangement, using the catalytic action of certain substances. Well all you do with tetra-ethyl lead is you add lead as a catalyst,

and raise the critical temperature of the hydrocarbon so it will not give off free hydrogen at operating temperatures and then the knock disappears.

MR. BERYLN: I would like to make one observation on the matter of starting a cold Diesel. On a larger engine the area of the boundary walls to the volume of air is so much lower that the heat of charge is conserved to allow it to do a job of vaporizing the fuel. The condition of the engine makes a difference again. I had a small engine that was difficult to start in cold weather and I was curious to know how much could be achieved by polishing the boundary walls of the combustion spaces. I not only cleaned the lampblack off, but I polished it, buffed it until it looked like a mirror in one cylinder, only, and I put it together and started it. It ran lustily on one cylinder whereas the other three didn't pick up. I shut it down for a while and let the whole engine get cold and started it up again, and I had to run to 500 r.p.m. on one cylinder, which was overloaded, and then, one by one the other cylinders cut in.

On a subsequent shutdown I polished all of the walls and when I started it up again it hit on all cylinders, and at a low temperature—and we get plenty of opportunity to start an engine in cold weather in Canada, where lubricating oil has the viscosity of a phonograph record.

I would like to ask Mr. Fiedler a question that has been on my mind. In connection with Diesel knock Mr. Fischer referred to a very low rate of pressure rise as expressed in pounds per square inch crank throw. One has heard that if you can keep it below even 30 lbs. to the square inch that combustion will be quiet, and if the pressure rise rate is at or above 50 lbs. there begins the usual good old wallop in the engine. I would like to have his views on that. I would like to know what is the highest rate of pressure rise which Mr. Fiedler has achieved with quiet combustion.

MR. FIEDLER: We have a rather unusual answer to that. We find that the rate of pressure rise does not mean a thing. In fact we want to get as rapid as possible a rise because that means economy. Where you have to make a difference is in the definition of the pressure rise. Detonation is a reaction without volume at all, although at the point where the re-

action occurs the temperature is so high that it burns any metal in the vicinity. The other reaction we want to try to complete as fast as possible and we control this rate by the number of holes in the valves because each spray forms its own ignition center. Each spray that hits the air forms a mixture, and produces an ignition center.

If you have a slow speed engine you want less spray holes because you don't want a knock—not a Diesel knock—but you don't want something that runs rough. But you can run into a condition where the engine runs away with the combustion and then you have to speed up the combustion—add more ignition center—like on the gasoline engine—add more spark plugs. But there are two reactions—detonation is so fast you can't control or record it; while a smooth combustion you can record, and I don't think you can make it fast enough.

I would like to go back to one thing—when Mr. Fischer talked of the air injection engine. That was interesting because it proves we are on the right track. With that engine you form a rich mixture of hydrocarbon and air, but in addition to that you expand your injection air into the cylinder, which has a definite cooling effect on the mixture which you inject, so you avoid vapor injection and, at the same time have established a rich mixture, and the injection product is in the direction of a rich mixture. What the ideal mixture ratio is, we don't know as yet. We have tried to run experiments, but have not completed them. The foregoing explains why the air injection engine runs so smoothly, and why it will detonate if you have a leaky valve—which happened in the case which I started to tell you about, at the beginning, this evening, where the engine exploded. We later found that the valve body had a crack, and although I hadn't given the engine any fuel, due to the priming of the system the fuel had leaked into the cylinder and on the first compression stroke there was enough vapor accumulation in the cylinder to destroy the engine.

MR. FISCHER: I wanted to say something about starting: We never had any explosion in here (referring to diagram he had previously put on board). Why? Because we separated the starting air from the fuel injection and air injection.

First of all we put the starting air on separately and so prevented any possible explosion. Of course we had explosions in the starting line. If you can conceive this engine—it was 33 feet long and you let the air in at 300 lbs., that causes compression, and the slightest trace of oil starts an explosion—and at the far end here we cause the damage. With respect to detonation: I forgot to mention before, if you have an indicator card (drawing) like this and you get here a sharp rise, and you have a 20 lb. pressure rise, that combustion will be harsh. If I have a card like this, where you get a slow lift like this—(drawing) it won't be as harsh as this first one. Now in the latter effect we got the combustion which Mr. Fiedler tried to explain. I believe we are similar on this type. I am showing our double load feature now (Making another diagram). That is our chamber (Describes engine from diagram). In other words, I push the burning fuel which is rich and which is lacking air and it rises slightly here, and when the air comes in and blows the rich mixture into that air, then you have the flame in front of the mixture, and it burns instantaneously and it makes a smooth combustion.

Now I always look at the L-head gasoline engine and when I hear it run I think, why can't we make a Diesel engine run like that. If you live with them of course you think it is good, so once in a while you have to go to the other engine and then you will know what a good engine sounds like.

CHAIRMAN WETHERILL: It is getting late. I am sure Mr. Fiedler will be glad to answer questions anybody may want to ask, but in view of the lateness of the hour I am going to adjourn the meeting and then you can hold forth in an informal discussion.

INFORMAL DISCUSSION.

MEMBER: On a gasoline engine the explanation of a knock is good, and to overcome it we go to a more aromatic type of fuel which doesn't knock, on the assumption that the aromatic type of fuel does not dissociate as do the paraffinic types. As we get to the Diesel, however, we do the reverse; we increase the paraffinicity of the fuel. I would like to ask

Mr. Fiedler why that is, and also what benefit this has in reducing the paraffinicity.

MR. FIEDLER: Well, the reason that a paraffinic fuel tends to soften the engine performance is it is more easily ignitible. It doesn't improve the performance of the engine but it does make it softer. I think, though, it is the incorrect way to solve the problem. We run on a straight fuel oil, a household fuel oil, which is fairly hard igniting fuel. We do it because we need the ignition lag to form our mixture. You will readily see that if you follow the other thought, you will get into trouble.

One pet theory of the Diesel engineers is the pilot injection. We have a combustion chamber here (drawing diagram) and you start out with the pilot injection. Let us assume that will find its proper auto-ignition ratio and will start combustion. The next fuel that follows is injected into combustion itself, which is certainly not the thing to do, because you are adding a hydrocarbon into a zone of low oxygen—and the same is true of a paraffinic fuel because you inject and get a short ignition delay, and before you get mixture in the chamber you get combustion resulting in sooty exhaust which you see on any of the standard Diesel engines. If you drive to New York you meet trucks on the road that have the exhaust on the side of the cab. The reason is not because the exhaust smells bad but because sometimes the Diesel engine has a habit of discharging a large amount of dark, smelly carbon from the exhaust, which tends to blind the driver at the rear. That is why, when the new tunnel was opened they would not permit Diesels to go through; they were afraid of collisions.

Going back to the fuel problem, using easy igniting fuels is the wrong way to go about it—you should work the other way around and use fuels that are commercial, which means they are harder to ignite. This gives more ignition lag and more chance to get a good mixture, resulting in complete combustion.

As to Mr. Fischer—I believe at the present time the only practical system is the Lanova System. I don't know if he agrees with me, but he is doing a similar thing in a different way. I think he agrees if he had very fine atomiza-

tion out of the nozzle his performance would not be any good. He uses a rather course spray, injects it into the chamber and the resulting rich mixture is backfired by the ignition—in the cell—he gets a rich mixture which burns progressively, as it finds the additional air in the main chamber, which seems to be a very good system. But I think you can get the same result without the chamber by direct injection, and are then not limited to speed.

MEMBER: I just wanted to ask this: You were speaking of the number of points of ignition—that is, the number of outlets through the nozzle. Wherein does this theory you present differ from the General Motors nozzle?

MR. FIEDLER: General Motors uses very much higher pressures. We use 1,200 lbs. and they use 25,000 lbs. injection pressure. In my opinion that is the worst thing you can possibly do.

CHAIRMAN WETHERILL: Gentlemen, it is getting late. I think we are through. The meeting is adjourned.

...Adjournment...

Green Lint Cotton Valuable for Wax.—Green cotton with thirty times as much wax as ordinary white varieties offers possibilities as a source of wax for polishes, the Department of Agriculture reports. Manufacturers of polish for shoes, furniture, floors, and automobiles need waxes with relatively high melting points. They have relied largely on imported wax, but shipping difficulties have stimulated interest in domestic sources. One chemical company is now growing experimentally in South Carolina about five acres of Arkansas Green Lint Cotton to determine its value as a source of high-melting-point wax. This cotton is one of three green lint strains collected by the Bureau of Plant Industry for genetic and other studies. The wax content of ordinary white cotton is only about one-half of one per cent., but Arkansas Green Lint sometimes yields seventeen per cent. This cotton has been grown in the south for years, chiefly for home spinning and handicraft work. Though the staple length is short—about thirteen-sixteenths of an inch—spun yarn is very smooth and has average strength for this length. High wax content keeps it from taking dye well unless specially treated. The lint in freshly opened bolls is bright green, but when exposed to sunlight the fibers and yarn or cloth made from this cotton gradually turn dull brown. With good growing conditions, Arkansas Green Lint yields approximately 250 pounds per acre, from which chemists can extract with alcohol or other solvents thirty to thirty-five pounds of wax. At a conservative price of sixty-cents a pound, the average crop would be worth about $19.50 per acre for wax alone, and after the wax has been taken out the fiber provides a high-grade cellulose.

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

NEW WEIGHTS AND MEASURES HANDBOOK.

Handbook H26, "Weights and Measures Administration" by Ralph W. Smith, released a short time ago, presents a general discussion of weights and measures supervisory work, as this should be carried on by State and local regulatory officers. Beginning with a statement of the functions of the weights and measures officials and a tabulation of the present organization of weights and measures administration in the United States, Part I of the text proceeds to a consideration of a model form of weights and measures organization, fee and licensing systems, essential elements of the law, the training of officials, and other general subjects. Part II deals with those activities of the official which have to do with scales, weights, measures, etc., treating separately such topics as standards and equipment, and the testing, sealing, rejection, adjustment, and repair of commercial equipment.

The supervisory side of weights and measures administration, as distinguished from the mechanical side, is discussed in Part III; the education of the users of commercial equipment and of the public, try-out inspections, the investigation of complaints, and prosecutions are among the subjects treated. Part IV is devoted to systems of weights and measures records. Three appendixes are included, the first presenting Federal weights and measures laws and regulations, the second giving the full texts of the three forms of the Model State Law on Weights and Measures, and the last listing the specific items of standards and equipment recommended for State and local departments of weights and measures.

The Handbook has been prepared to provide basic information for weights and measures officials, to encourage the extension of weights and measures supervision to communities not now enjoying that protection by providing facts for the

* Communicated by the Director.

study of the subject by consumer groups and others, and to supply data for the enactment of laws and the establishment of adequate regulatory agencies in the weights and measures field. The non-technical reader will find the subject matter presented in understandable terms. Copies of H26 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. at 75 cents each.

POLAROGRAPHIC STUDIES OF SUGAR ACIDS.

In the *Journal of Research* for January (RP1448), Harry Matheson, Horace S. Isbell, and Edgar Reynolds Smith describe the polarographic method of studying the polyhydroxymonocarboxylic acids, often called the "sugar acids," and their lactones, lactides, and other condensation products. The approach to equilibrium between the aldonic acids and their lactones is shown by progressive changes with time in the relative heights of the hydrogen and lactone "waves" on current-voltage curves, as the acid or lactone is allowed to stand in dilute aqueous solution.

Freshly prepared solutions of the aldonic acids give the ordinary hydrogen wave, but do not give waves which correspond to the reduction of the carboxyl group. When a solution containing an aldonic acid is allowed to stand, the wave caused by hydrogen ion decreases, and a wave due to the gamma lactone appears. In the presence of oxygen, a wave apparently caused by some substance produced by the interaction of the sugar acid, mercury, and oxygen, forms at about -1.1 v. The formation of this wave is accompanied by a corresponding decrease in the hydrogen wave.

Freshly prepared solutions of the delta lactones of the aldonic acids give waves at about -2.3 v, with respect to a mercury anode, which appear to result from the reduction of the lactones. The heights of these waves decrease with time until, after several hours, they disappear. The absence of an appreciable delta lactone wave in a 0.01 *M* aqueous solution of an aldonic acid shows that the position of the equilibrium between the free acid and the delta lactone is far toward the free acid.

The gamma lactones of the aldonic acids give polarographic waves at potentials slightly higher than the delta lactones. When a solution containing a gamma lactone is allowed to stand, the height of the gamma lactone wave decreases, while a wave corresponding to the reduction of the hydrogen ion appears. The inflection points for the gamma lactone waves vary only slightly with the configuration of the groups comprising the lactone structure. This small variation in the inflection points shows a regularity which indicates that the stereomeric positions of the hydroxyl groups are of importance. When the hydroxyl of carbon 2 and the residual carbon group attached to carbon 4 are in the *cis* position, the reduction potential seems to be higher than it is when these groups are in the *trans* position.

ELASTIC PROPERTIES OF ALLOY CAST IRONS.

A knowledge of the elastic properties of cast iron is important in connection with the design of structural parts, such as piston rings, cylinder liners, etc. This is particularly true at the present time when emergency conditions have greatly increased its use. Therefore, A. I. Krynitsky and C. M. Saeger, Jr. have extended their previous study of elastic properties to include three types of alloy cast iron. Test bars 1.2 inches in diameter and 21 inches long were made and tested for transverse strength, deflection, Brinell hardness, and microstructure. The metal was melted in a high-frequency induction furnace of the tilting type. It was heated before casting to the maximum temperatures of 1,400°, 1,500°, 1,600° and 1,700° C. (2,552°, 2,732°, 2,912° and 3,092° F). Test bars were vertically cast, bottom poured in green sand molds at a temperature 100°, 150°, 200° and 250° (180°, 270°, 360° and 450° F) above the liquidus.

As reported in RP1447 in the *Journal of Research* for January, a comparison of the results for alloy irons with those of plain carbon irons examined previously indicates that the relative modulus of elasticity of some carbon irons is higher than those of the alloy irons investigated.

The beneficial effect of the maximum heating temperature on the moduli of rupture and elasticity was more pronounced

for the plain carbon irons than for alloy irons. The effect of pouring temperature for both plain carbon and alloy irons was about the same, i.e., these properties showed a tendency to increase with a decrease in pouring temperature.

TEE BEND TEST FOR WELDING QUALITY OF STEELS.

The marked increase in the use of welding in place of riveted construction has involved more than a simple substitution of one method for the other. A design for riveted construction is not necessarily equally suitable for welding; in fact different designs are often necessary for identical structures fabricated by the two methods. All metals are not equally satisfactory for welding, and different techniques are necessarily employed for making the same types of joints in different metals. In selecting the metal that will best meet the strength requirements of a given structure to be assembled by welding, the welding quality of the metal (within the limitations imposed by the practicability of the welding method) is of prime importance.

The welding of medium steel offers little difficulty, provided proper attention is given to design and welding technique. However, the use of high tensile low alloy steels to reduce size and weight of members often creates difficulties because of the differences in welding qualities of the steels.

In a coöperative investigation authorized by the Bureau of Ships, U. S. Navy Department and conducted by George A. Ellinger, A. G. Bissell, and Morgan L. Williams at the National Bureau of Standards, the welding qualities of eighteen commercial steels were studied by bending fillet-welded tee specimens of the steels in special jigs. Six of these steels were also welded and tested at subnormal temperatures as low as $-20°$ F. The welds in the specimens were not machined.

The angle of bend at maximum load and the type of fracture in the bend test were the governing factors in comparing the welding qualities of the steels. The data were evaluated by means of a special method of statistical analysis.

As reported in the *Journal of Research* for January (RP1444), steels which contained large numbers of non-

metallic inclusions generally had lower welding qualities than those which contained few inclusions. The high temperature grain size and grain coarsening temperatures apparently had little effect on the welding qualities of these steels.

Steels normalized at 1,650° F. before welding had higher welding qualities due probably to more homegeneous structures of the metals.

Hardness surveys indicated that none of the steels hardened appreciably upon welding and that there was no correlation between hardness properties and welding qualities as determined by this investigation. Likewise, no good correlation was found between the ordinary tensile properties (yield point, tensile strength, and elongation) and welding qualities of these steels.

Steels welded at low temperatures usually had lower angles of bending and a higher percentage of failures in the parent metal than those welded at room temperature. However, the temperature at which the tests were made apparently had more effect on the results obtained than the temperature of the plates when welding was started.

Bend tests made on specimens of the same steel with cast fillets and with welded fillets proved that the test was not a function of the geometrical shape of the specimen but was an indication of the welding quality of the steel. Likewise, the width of specimen is not critical and within certain limits does not appreciably affect the results of the bend tests.

CATHODIC PROTECTION OF PIPE LINES.

In Technical News Bulletin 296 (December, 1941) a résumé was given of the present status of cathodic protection of pipe lines. A paper on this subject was presented by Kirk H. Logan at the Second Annual Water Conference of the Civil Section of the Engineers' Society of Western Pennsylvania, November 3, 1941. A limited number of mimeographed copies of this paper are now available and will be sent on request to applicants who can show a real need for the information. Requests should be addressed to Underground Corrosion Section, National Bureau of Standards, Washington, D. C.

WATER-DISTRIBUTING SYSTEMS FOR BUILDINGS.

A common and exasperating experience in the average home is the complete or nearly complete failure of the water supply on the upper floor caused by the simultaneous use of several fixtures on the lower floor, thus overloading the water-distributing system in the building. The difficulty is due to the fact that the sizes of the building supply main and of the branches for a small dwelling are rarely designed, but are selected by a hit-or-miss process which leads to unsatisfactory service in times of maximum water use in the building.

Even if the pipe sizes are chosen to give an adequate supply of water when the system is new, the supply may become inadequate in the course of time because of the deterioration of the inner surface of the pipes owing to corrosion or caking by the water that flows in them. This deterioration leads to increased resistance, resulting in a decrease in the rate of flow that can be obtained at any given fixture.

Different water supplies vary markedly in their caking and corroding effects on pipes. In some parts of the United States, hot-water pipes of the most commonly used material must be renewed annually on the average, whereas in other localities the same kind of pipe may give good service for 20 years or more. Under most conditions satisfactory service can be assured over a reasonable period of years by using pipes of suitable material and by selecting large enough pipe diameters for the various parts of the system.

Building Materials and Structures Report BMS79, recently released, is intended to make available for practical use a method of procedure for sizing the pipes properly in designing building water-distributing systems. It also gives information that will aid in choosing proper materials for use in the piping system, a subject on which little has been published in usable form.

The paper is one of a series which will deal with all aspects of the water supply and drainage in buildings. An earlier paper (BMS65) in the series described a practical method of estimating the maximum rate of flow of water in a building water-supply system based on the number and kind of plumbing fixtures installed in the building.

Copies of BMS79 are obtainable at 15 cents each from the Superintendent of Documents, Government Printing Office, Washington, D. C.

KNOCK RATING TESTS AT VARIOUS ALTITUDES.

Laboratories making knock rating tests of gasolines are located at various altitudes. Since the results are directly affected by barometric pressure, the tests run in these laboratories are not consistent with each other. This has been a source of both inconvenience and error for some years, during which attempts have been made with only partial success to reconcile the results. Recently a program of comparative tests was completed in the Bureau's altitude laboratory where air pressures are readily controlled. Engines and observers were assigned by some of the oil companies. The results are gratifying, as it is found that a very simple formula can be used with high accuracy to correct the results of tests run at any altitude below 10,000 ft. to correspond with those obtained at any other altitude.

New Electron Microscope Technique Broadens Studies of Grain Structure of Metals.—With important results for defense and civilian industry indicated by preliminary studies of heavy armor plate and various carbon steels, RCA Laboratories have announced development of a new technique that permits heretofore impossible microscopic examination of the grain structure of metals. Using the new process in connection with the RCA Electron Microscope, designed to accommodate only very thin transparent objects, laboratory technicians obtain detail in metal surfaces that is at least fifteen times finer than results with the best metallographic microscope. Pointing up the significance of the technique in national defense work, electron micrographs of heavy armor plate grain structure were exhibited at the recent National Metals Congress Meeting in Philadelphia. They were produced by Dr. Robert F. Mehl, director of the metals research laboratory of Carnegie Institute of Technology, in collaboration with Dr. Vladimir K. Zworykin, associate director of RCA Laboratories. It is possible, using peak magnification, to identify particles of only fifty atoms or six ten-millionths of an inch apart. Ordinarily, specimens to be viewed in the electron microscope are mounted on an extremely thin film of transparent collodion for direct examination. The new technique involves the making of an exact replica of the metal's grain structure in collodion. The replica, of about one-half inch of etched metal surface, is made in three steps. A layer of silver is first evaporated onto the metal surface, thick enough to be stripped off mechanically. Then a drop of collodion dissolved in amyl acetate is sprayed on the under side of the silver, filling over the hills and valleys in the silver surface. The silver is then dissolved in dilute nitric acid, leaving the collodion layer intact. This positive replica in collodion is mounted in the microscope. Variations in the thickness of the replica correspond to the irregularities in the original metal surface, and are reproduced on the screen or photographic plate in the microscope as variations in brightness.

R. H. O.

THE FRANKLIN INSTITUTE.

ANNUAL MEETING, JANUARY 21, 1942.

The annual meeting of The Franklin Institute was held at 8:15 o'clock on the evening of Wednesday, January 21, 1942, with Mr. Charles S. Redding, President, presiding.

Dr. John D. Mahoney, of the United Charities, spoke briefly about the campaign for funds and urged the assembly to contribute in order to keep management of organized charity within the control of the organizations represented.

The President, Mr. Redding, then took over the meeting and announced that the minutes of the previous meeting had been printed in full in the January number of the Journal. They were approved as published.

The Chairman called upon the Secretary, Dr. Henry Butler Allen, who reported the following additions to membership since the last meeting:

Active	18
Associate	15
Student	44
Total	77

He then read the report of the Tellers of the annual election, which follows:

President (to serve one year)	Charles S. Redding
Vice-Presidents (to serve one year)	Walton Forstall
	W. Chattin Wetherill
	S. S. Fels
	Richard W. Lloyd
	Richard T. Nalle
Treasurer (to serve one year)	M. M. Price
Managers (to serve three years)	Edward G. Budd
	Clarence A. Hall
	A. Atwater Kent
	William F. Kurtz
	Orus J. Matthews
	George W. Pepper
	James S. Rogers
(to serve two years)	Philip C. Staples

Respectfully submitted,
GEORGE S. CRAMPTON,
GEORGE S. CULLEN,
J. LOGAN FITTS,
Tellers.

January 21, 1942

The gentlemen named were then declared elected for the term of office indicated.

In the name of the Institute, Dr. Allen expressed the appreciation of the members and officials to the Tellers for the service they had rendered.

He then called attention to the fact that the Library of the Institute was equipped and ready to serve the technical and research workers in this community, and then presented a resumé of the report [1] of the Librarian.

The annual report [1] of the President, for the Board of Managers, on the affairs of The Franklin Institute, was then discussed by the Chairman.

The Chairman introduced the speaker of the evening, Mr. E. R. Bridgwater, Manager, Rubber Chemical Division, E. I. duPont de Nemours and Company, Wilmington, Delaware.

Mr. Bridgwater chose as his subject, "Synthetic Rubber," a subject of interest to everyone in the disturbed state of the world today. He outlined the search for a substitute for rubber and told the story of the development of synthetic rubbers in other countries as well as in the United States. He then spoke at some length concerning the physical characteristics of these various rubbers and described how, in many cases, for many purposes, they are better than natural rubber, while in other cases they are less satisfactory. He also spoke of the future technical and commercial possibilities of these synthetic rubbers.

The talk was followed by much spirited discussion.

The Chairman adjourned the meeting by a rising vote of thanks to the lecturer, at nine-forty P.M.

HENRY BUTLER ALLEN,
Secretary.

Report of the President to the Board of Managers of The Franklin Institute of Pennsylvania, Covering the Operations of the Institute for the Year 1941 and Adopted by the Board as Its Report to the Membership of the Institute for that Year.

This is a report, necessarily brief, of the financial and other results of operation for 1941.

The property of the Institute is entered on its books at $5,704,000. Of this amount, real property (the building and equipment, not including those exhibits which have been donated) amounts to $4,109,300, and personal property (principaplly securities, as referred to later) amounts to $1,594,700.

Not entered in its books, except statistically, is certain other property consisting of exhibits et cetera which came to the Institute as gifts and which is estimated to have a replacement value of $856,750.

Income for 1941 consisted of the following, set forth comparatively with 1940 figures:

	1941 [2]	1940
From dues	$22,700	$24,000
" admissions	42,600	49,900
" investments	74,300	68,400
" other	48,600	44,800
" Friends of Franklin (net)	30,200	26,400
	$218,400	$213,500

[1] Published in full in this issue.

[2] These figures are subject to minor adjustments when the books are closed.

Expenses for 1941, with same comparison, were as follows:

	1941 [2]	1940
General	$140,000	$154,200
Museum Operation	95,000	121,500
Publications	11,600	12,800
Meetings, etc.	1,800	1,650
Other	13,600	7,300
	$262,000	$297,450

The deficit for 1941 was, therefore, $43,600, as compared with $83,950 in 1940.

Annual Report.

At the end of 1941 the investments in securities were:

Largely available as to income only	$ 581,700
Available unrestrictedly	1,013,000
	$1,594,700

The membership, all classes, was 3,956 at the end of the year.

Admissions were as follows, with comparative figures for 1940.

	Museum		*Planetarium*		*Total (A)*	
	1941	1940	1941	1940	1941	1940
Paid at 25¢ rate	84,206	92,633	52,678	73,825	136,884	166,458
Paid at various special rates (*B*)	32,036	26,647	27,626	31,362	59,662	58,009
Free, Phila. School Children	25,974	31,161	10,308	12,048	36,282	43,209
Free, Members	9,712	11,566	8,518	12,592	18,230	24,158
	151,928	162,007	99,130	129,827	251,058	291,834

(*A*) Included in the 1941 total are a portion of the 51,500 who visited Franklin Memorial Hall without charge.

(*B*) Special rates for sizeable groups and for the Christmas season.

During the year 14 lectures were held; and, altogether, there were 300 meetings of various kinds held at the Institute.

Only lack of space in this report prevents a review of museum and planetarium activities, which are limited only by the insufficiency of funds for greater expansion.

The work of the various committees of the Institute was carried on during 1941 with notable and very effective attention on the respective affairs of the several groups. Much that they have accomplished is evidenced to all who visit the Institute and its Museum and who read its publications.

The Hostess Committee, composed of ladies who have a particular interest in the Institute, was of great service during the year in a broad range of matters. Its assistance in the furnishing of two recreation rooms for the use of the staff is recorded with appreciation.

The two Foundations, Bartol and Biochemical, continued to be industriously engaged in their respective fields of research with the allocation of part of their staff and facilities for National Defense research. Their Directors make annual

[2] These figures are subject to minor adjustments when the books are closed.

reports at stated meetings of the Institute on the accomplishments of the Foundations. Financial statements of operation of the two Foundations are not included in this report for the reason that each has its own funds, disassociated from those of the Institute and not contributed to by the latter.

On December 31st the organization comprised the following employees, including salaried and non-salaried:

The Franklin Institute	133
Bartol Research Foundation	23
Biochemical Research Foundation	61
	217

It is desired to compliment the men and women of the organization on their earnest and effective service during 1941, despite handicaps in Institute operations which must be apparent to all who follow our affairs closely. Inadequacy of income, from our several sources, very much limits the staff in the expansion and perfection of our exhibits and activities. In order to control expenses and to reduce financial deficits in operation, the hours of admission to the museum were held to the following schedule:

Tuesday, Wednesday, Thursday, Friday and Sunday, 1 P.M. to 6 P.M.
Saturday, 10 A.M. to 6 P.M.

It is regrettable that necessary economies must be accomplished in such fashion. Altogether, the organization is at present insufficient in numbers to do the well-rounded museum job which the staff and the officers desire. Operations are cramped in a number of very important respects by reason of necessarily curtailed appropriations. The entire organization knows this and carries on with high spirit in face of handicaps which are both general and individual.

As the year progressed, more and more of the museum effort was given to problems of National Defense; developing ways and means for usefulness. It is the expressed purpose to develop every possible field of effectiveness in the war effort.

The figures contained in this report have been furnished by the Secretary and Controller.

The report is made to the Board of Managers by

CHARLES S. REDDING,
President.

It is made to the membership of the Institute on behalf of the Board of Managers by

CHARLES S. REDDING,
President.

Philadelphia, Pa.
January 21, 1942

Report from the Librarian.

January 15, 1942.

DR. HENRY BUTLER ALLEN, *Secretary.*
My dear Doctor:

I am submitting herewith, for your information, a statement of the library during the past calendar year.

The additions to the library were as follows:

	Bound Volumes.	Unbound Volumes.	Pamphlets.	Maps.
By gift	228	375	738	70
binding				
magazines and society transactions	302			
patents	1,150			
purchase	345	41		
	2,025	416	738	70

Total additions, of all kinds, during the year—3,249.

Gifts were received from Mr. W. H. Grovell, Dr. Henry A. Gardner, Mr. George D. Firmin, Mrs. H. C. Cumings, General Electric Company, The Historical Society of Pennsylvania, Dr. Joseph S. Hepburn, National Archives Project, Mr. Alfred P. Sloan, Jr., American Petroleum Institute, Mr. Bernard M. Baruch, Dr. Clarence F. Schmidt, Jr., Mr. Rodich M. Boehmke, Mr. Cyrus Adler, Mr. Lee P. Hynes, Miss Lillye Armstrong, Miss Amanda Ford, Mr. E. B. Wedmore, Mrs. A. S. Woodle, Jr., Mr. Errol J. Gay, Mr. Paul Thomas, The Athenaeum of Philadelphia, Mr. W. A. Welch, Yale Metallurgical Alumni and The Baldwin Locomotive Works.

The thanks of the Committee on Library are also due Mr. R. H. Oppermann, who has given a great number of books which he reviewed from time to time in the JOURNAL.

Our attendance for the year was slightly less than the former year, but much more material was consulted.

The present crisis has called for much research in physics, but chemistry still leads in all the material consulted.

We have been able to bind a few more volumes of periodicals than the usual number, as we are now doing our own binding of the United States Patent Specifications.

During the year, we removed 2,243 duplicate volumes and pamphlets from our collections.

The total contents of the library on January 1, 1942 were:

123,590 volumes
42,045 pamphlets
3,449 maps

During the past year 6,495 members and 1,622 non-members consulted the collections.

There were 3,545 telephone calls for technical information.

Respectfully submitted,
WALTER A. R. PERTUCH.

RESOLUTIONS PASSED BY THE BOARD OF MANAGERS ON THE OCCASION OF THE DEATH OF MR. WILLIAM H. WINTERROWD.

THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE, sensible of the loss which has been sustained through the untimely death of WILLIAM H. WINTERROWD, unanimously—

Resolves: That there be recorded in its minutes this testimony of the faithful service and enthusiastic coöperation given by Mr. Winterrowd, which, together with a dynamic personality, not only made him a valuable member but also endeared him to his associates, by whom he was held in highest esteem.

Resolves further: That this minute be published in the JOURNAL of the Institute and that a copy thereof be transmitted to the family of Mr. Winterrowd.

CHARLES S. REDDING,
President,
HENRY BUTLER ALLEN,
Secretary

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, January 14, 1942.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, JANUARY 14, 1942.

MR. COLEMAN SELLERS, 3RD, *in the Chair.*

The following report was presented for final action:

No. 3104 } The Standing Sub-Committee on the Franklin Medal recom-
No. 3105 } mended that a Franklin Medal be awarded in 1942 to:

PAUL DYER MERICA, of New York City, New York, "In recognition of his theoretical work on the precipitation hardening of alloys, and of his practical work in the development of the art of heat treatment of such alloys to the end that they acquire properties which make them commercially of greater usefulness"; and one to

JEROME CLARKE HUNSAKER, of Cambridge, Massachusetts, "In recognition of his pioneer work in education in the field of aeronautical science, and of his many invaluable contributions to that science."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays from two until ten o'clock P.M.

RECENT ADDITIONS.

AERONAUTICS.

LEY, WILLY. Bombs and Bombing. 1941.

ARCHITECTURE AND BUILDING.

GIEDION, SIGFRIED. Space, Time, and Architecture. 1941.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

BLANNING, H. K., AND A. D. RICH. Boiler Feed and Boiler Water Softening. Second Edition. 1935.

Rubber Age. Bibliography of Rubber Literature 1935–1939. Four volumes. 1936–1940.

STEINER, LUKE E. Introduction to Chemical Thermodynamics. First Edition. 1941.

STRAIN, HAROLD H. Chromatographic Adsorption Analysis. 1942.

ELECTRICITY AND ELECTRICAL ENGINEERING.

British Electrical and Allied Industries Research Association. Surge Phenomena. 1941.

COOK, ARTHUR L. Elements of Electrical Engineering Fourth Edition, Thoroughly Revised. 1941.

CORCORAN, GEORGE F., AND EDWIN B. KURTZ. Electrical Engineering Fundamentals. 1941.

Radio Handbook. 1941.

ENGINEERING.

American Society for Testing Materials, 1941 Supplement to A. S. T. M. Standards, Including Tentative Standards. Three Volumes. 1941.

MARINE ENGINEERING.

FORD, LOUIS R. Practical Marine Diesel Engineering. Third Edition. 1941.

MINING AND METALLURGY.

READ, THOMAS THORNTON. The Development of Mineral Industry Education in the United States. 1941.

NAVAL ARCHITECTURE, NAVIGATION, ETC.

ACKERMAN, EDWARD A. New England's Fishing Industry. 1941.

BREWINGTON, M. V. Chesapeake Bay Bugeyes. 1941.

CHAPELLE, HOWARD I. Boat Building. 1941.

HUTCHINS, JOHN G. B. The American Maritime Industries and Public Policy, 1789–1914. 1941.

PHYSICS.

Rheological Memoirs Volume 1, Number 1. 1940.

SWANN, W. F. G. Physics. 1941.

WILSON, W. KER. Practical Solution of Torsional Vibration Problems. Second Edition. Volume 2. 1941.

RAILROADS, TRANSPORTATION, ETC.

BEEBE, LUCIUS. High Iron. A Book of Trains. 1938.

KAHN, EDGAR M. Cable Car Days in San Francisco. 1940.

KNEISS, GILBERT H. Bonanza Railroads. 1941.

Locomotive Cyclopedia of American Practice. 1941.

WINTHER, OSCAR OSBURN. Express and Stage Coach Days in California. 1936.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Treatment of Infected Wounds by H-1, a New Germicidal Extract from Soil Bacilli Cultures.—V. W. MURRAY WRIGHT, M.D., F.A.C.S. Clinical observations were made on the effect of a new organic germicide extracted from cultures of soil bacilli, which is specific for gram-positive microörganisms. This substance, which has been designated H-1, is colorless and thus makes it possible to watch more easily the developments in the wound. No local toxic effect nor any protein-coagulating effect such as is commonly found with the use of many inorganic germicides was observed.

In the 90 infected cases treated, beginning January 1940 in several different Philadelphia hospitals and clinics, H-1 has been a very efficient germicide where the infection was caused by a gram-positive organism or by a combination of gram-positive organisms. Most war wounds are caused by gram-positive organisms. In cases of infection from gram-negative organisms, the germicide was of little effect. In cases, however, which have been primarily infected with gram-positive organisms and secondarily with *B. pyocyaneus*, both organisms have rapidly disappeared from the wound when it was treated with H-1, to which had been added acetic acid to a concentration of 1 per cent.

In addition to its germicidal effect, it appeared to stimulate healing, for many wounds and some skin grafts treated with H-1 healed in a remarkably short time.

H-1, the material used in this study, was prepared by the Biochemical Research Foundation. It was obtained from culture filtrates of a gram-positive organism isolated from soil. A cell-free solution of the active principle was obtained by precipitation of a 7-day-old culture by the addition of electrolytes and a small amount of HCl. This precipitate was purified by solution in alcohol and extraction with ether, petroleum ether and benzol. A very complete study was reported from the Biochemical Research Laboratories and this

included an analysis of the crystalline component, a description of the crystals with photographs, the specific rotation, the spectrographic absorption curve, the chemical properties, bacterial activity, toxicity and a preliminary report of its use on human infections in 15 cases up to June 1940 (McDonald, JOURNAL OF THE FRANKLIN INSTITUTE, **229**: 805, June 1940). H-1 is somewhat similar to the substance described by Dubos (*Journal of Experimental Medicine*, **75**: 629, 1941).

H-1 was found to be highly bactericidal for all species of gram-positive organisms tested. An amount as low as 0.0005 mg. per cc. of broth completely prevented growth of Pneumococci and 0.00001 mg. per cc. broth showed a slight but definite inhibition of the growth of *Gaffkya tetragena*. In addition to this germicidal effect on gram-positive organisms H-1 was found to inhibit very strongly the encapsulation of Friedländer's bacterium. Encapsulation was inhibited by a concentration of 0.000005 mg. per cc.

Animal experimentation.—Suspensions of H-1, tested in mice, were found to be somewhat toxic when injected intravenously, subcutaneously, or intraperitoneally. Daily doses of 20 γ (.02 mg.) injected intravenously in 5 per cent. glucose solution were not tolerated by mice. The intraperitoneal toxic dose was about the same as the subcutaneous toxic dose, 200–300 γ (.2–.3 mg.) Administered orally or rectally the material was without activity, either toxic or bactericidal. Mice withstood a single dose of 4 mg., given orally, without showing any toxic effects. The toxic dose for guinea pigs, administered intraperitoneally, was about 2 mg., although the animals tolerated 19 daily injections of 200 γ each, intramuscularly. There was some myositis at the site of injection.

This germicide is for external use only and not for intravenous or intraperitoneal injection.

Preparation of solutions for clinical use.—The grayish-white powder was dissolved in 70 per cent. alcohol to give a 5 per cent. solution. The solution was sterilized by filtration through a Seitz E-K filter and was sprayed by means of a syringe and a fine needle into sufficient sterile distilled water. The water was contained in a large Erlenmeyer flask which was rotated vigorously while the alcoholic solution was being added, to insure a stable and finely divided suspension of the

active material. It was found necessary to use distilled water for making up the suspensions, rather than physiological saline solution, because of the tendency of the active material to precipitate from suspension in the presence of small amounts of electrolyte. The suspension was then placed in sterile screw-cap bottles.

Solution for treating large infected areas .... 10–20 parts per million
Solution for treating small infected areas .... 60–200 parts per million

Because the active principle of H-1 is precipitated when it comes into contact with electrolytes and some chemicals, wounds, treated previously with various antiseptics, vaseline gauze or salves, should first be thoroughly cleansed by irrigations of sterile water, preferably distilled.

The grayish powder is so potent that it is impossible to apply small enough amounts directly to large infected wounds. The method of application used, therefore, was first to irrigate the wound with H-1 solution and then to apply sterile gauze-packing saturated with solution of the same strength.

Most of the infections treated were caused either by Staphylococci or Streptococci or both. One of the cases of

TABLE 1.

Types of Cases Treated with Soil Bacilli Solution.

Infected lesions treated	No. of cases
Cellulitis and suppurations, extremities	18
Infected abdominal wound, appendicial abscesses	11
Suppurative adenitis	10
Infected diabetic lesions	8
Osteomyelitis	9
Infected leg ulcers	6
Breast abscesses	5
Infected burns	4
Superficial infections and abscesses	4
Carbuncles	4
Infected cancer lesions	3
Palmar abscesses	3
Sinusitis	2
Suppurative arthritis	2
Skin grafts	2
Infected liver cyst	1
Gas gangrene infection (*B. Welchii*)	1

suppurative arthritis was caused by Pneumococcus Type III and the case of gas gangrene was infected primarily with *B. Welchii* and *Strep. hemolyticus;* later when the treatment was temporarily suspended the wound became infected with *Staph. aureus*. The variety of infections treated is shown in Table No. 1.

Clinical results.—The results in these 90 cases have been very good, especially in those cases in which the infection was caused by a gram-positive organism. It was necessary to expose the pathological condition adequately by surgical means that the entire affected area be properly treated. Daily dressings were also found to be essential. When the infecting organism was gram-negative, or when the affected area was insufficiently exposed, the results were unsatisfactory.

In attempting to evaluate the clinical worth of soil bacilli extract as an adjunct to surgery, it has been difficult to find any index by which it could be compared with other germicides. Especially is this true in the treatment of superficial infections, for these are seldom near enough alike to allow one to be used as a control for another. Consequently, the only approach to this problem can be a clinical one, based upon experience in treating such conditions.

CASES.

Gas Gangrene.

Only one case of gas gangrene (*B. Welchii*) has been treated with soil bacilli extract solution but the effects were dramatic. The following case had failed to respond to sulfanilamide, X-radiation, permanganate irrigations, transfusions, etc.

Case No. 31, a 31-year-old colored male who had a bicycle handle bar driven into his upper thigh, carrying soiled clothing into the depths of the wound.

9/10/40 Bicycle accident. Lacerated wound of upper thigh. Sutured tight by family doctor.
9/11/40 Chill.
9/12/40 Pain and swelling of thigh.
9/16/40 Hospitalized. T. P. R. 102.0–108–33. B. P. 100/55. Three lacerations of upper thigh; swollen, crepitus. Sutures removed, wounds laid open. 5–6 oz. offensive fluid drained. Culture:—*B. Welchii* and *Streptococcus hemolyticus*.
9/17/40 Sulfanilamide (orally) started.

9/19/40 Jaundiced. X-radiation begun.
9/20/40 Sulfanilamide discontinued. R. B. C. 2,000,000. Transfusion—500 cc. $KMnO_4$ irrigations.
9/22/40 Anterior wound perforated posteriorly into gluteal region and portions of clothing extracted. 350 cc. transfusion. Dakin's irrigations.
9/23/40 Multiple incisions made, three drains inserted. Dakin's irrigations.
9/25/40 X-radiation (1400 R Units) completed. 300 cc. transfusion. $KMnO_4$ irrigations very toxic—foul drainages.
9/27/40 Culture:—*B. Welchii.*
Continuous drip irrigation of wound begun with soil bacilli extract solution (40–50 γ per cc.)
9/30/40 Sloughing tissue coming away. 600 cc. transfusion.
10/ 1/40 Better generally. Less toxicity.
10/ 2/40 Improving locally and generally. Talks clearly.
10/ 6/40 Only one tube left in 5-inch buttock wound. Packing saturated with soil bacilli extract solution inserted into wound with irrigations twice daily. Smear negative for gram-positive rods.
10/ 8/40 Drain out—wound edges healthy. Wet dressings only.
10/10/40 Out of bed.

On 10/14/40 patient developed swelling of thigh which was thought to be phlebitis. Later, incisions had to be made from the upper thigh to the knee and popliteal spaces for staphylococcic infection dissecting into different parts of the thigh. Patient discharged—12/14/40. However, no evidence of gas gangrene was encountered from 10/6/40 and subsequent cultures of the thigh showed only Staphylococcus.

The dramatic outcome of this case causes one to believe that surgical cases of gas gangrene should be treated not only by immediate and good surgery, with recognized supporting therapy, but also by continuous irrigations of the locally infected gas gangrene lesions with soil bacilli extract solution.

Osteomyelitis.

Case No.	Diagnosis.	Microörganism.	Result—Remarks.
20	Acute osteomyelitis of carpal bones	*Staph. aureus*	Daily irrigations through multiple incisions. Poor result due to location in joint spaces.
21	Chronic osteomyelitis of clavicle, eight years	*Staph. aureus*	Healed in 5 weeks. Daily irrigations. No recurrence in 18 months' follow-up.
28	Acute osteomyelitis of great toe	*Strept. hemo.*	Irrigations twice weekly for 3 weeks with fair result. Daily irrigations for 5 weeks with healing. O.K. 11 months later.

Osteomyelitis.—*Continued.*

Case No.	Diagnosis.	Microörganism.	Result—Remarks.
30	Chronic osteomyelitis of of femur, multiple sinuses	*Staph. aureus*	Irrigations through fine catheter for several weeks. Improved. Refused adequate surgical drainage.
59	Acute epiphysitis, os calcis	*Staph. aureus*	Discharged home on 13th day. No recurrence 6 months later.
60	Chronic osteomyelitis of humerus with sinuses	*Staph. aureus*	Daily irrigations for 1 week. Improved. Refused adequate incision and drainage.
70	Acute osteomyelitis of tibia (later skull)	*Staph. aureus*	Daily irrigations of tibia controlled infection. Developed extensive osteomyelitis of skull. Permitted to go home.
39	Chronic osteomyelitis, tuberosity of ischium	*Staph. aureus* *B. coli*	Daily irrigations. Discharged in two weeks, wound healing. O.K. 5 months' follow-up.
91	Acute osteomyelitis of tibia	*Staph. aureus*	Daily irrigations, drainage ceased on 30th day. Incised and drilled before irrigations started.

9 cases of osteomyelitis caused by gram-positive organisms have been treated by irrigations and saturated gauze packings of soil bacilli extract solution containing 40–100 γ per cc. (40–100 parts per million). Largely, the results have been very good where the affected area was adequately exposed surgically to the solution.

Miscellaneous Superficial Infections, Skin Grafts and Infected Burn Cases.

Case No.	Diagnosis.	Microörganism.	Result—Remarks.
16	5-year unhealed burn of thigh	*Staph. aureus, diphtheroids*	Soil bacilli solution, pinch grafts and soil bacilli solution. Grafts healed cleanly in 1 week.
71	Old leg burn	*Staph. aureus*	Soil bacilli solution, pinch grafts and soil bacilli solution. Healed in 10 days.
54	Palmar abscess	*Staph. aureus*	Incised, irrigated daily with soil bacilli solution. Hospitalized—7 days, discharged to clinic.
79	Palmar abscess	*Strep. hemo.*	Incised, irrigated daily with soil bacilli solution. Hospitalized—5 days, discharged to clinic.
82	Palmar abscess	*Strep. hemo.*	Incised, irrigated daily with soil bacilli solution. Hospitalized—2 days, discharged to clinic.
9	Frontal sinusitis	? yellow pus	Prompt relief in a few hours. Wet nostril packs twice daily. Resumed work in 2 days.

Miscellaneous Superficial Infections, Skin Grafts and Infected Burn Cases.—*Continued.*

Case No.	Diagnosis.	Microörganism.	Result—Remarks.
10	Maxillary sinusitis	? greenish yellow pus	Prompt relief in a few hours. Wet nostril packs twice daily. Resumed work in 1 day.
24	Infected liver cyst, 2 years' duration	*Strep. hemo.*, *B. pyocy.*	Temporary improvement only. Daily irrigations by catheter through small sinus tract.
18	Infected post auricular sebaceous cyst	*Staph. aureus*	Healed quickly in 3 days. Incised, daily wet gauze drains of soil bacilli solution.
75	Pilonidal cyst (infected)	*Staph. aureus*	Wound infected on 5th post-operative day. Wound opened, wet packs. Discharged 5 days later to clinic.
76	Pilonidal cyst (infected)	*Staph. aureus*	Discharged 9th day to clinic. Daily irrigations and wet packs of soil bacilli solution.
83	Gluteal bed sores, tuberculosis patient	*Strep. viridans*	Clean and healing—2 weeks. Healed in 6 weeks. Still O.K. 4 months later though a bed patient.
7	Infected burn of finger	*Staph. albus*	Infection ceased—24 hours. Dry dressings, 4th day. Fresh burn.
25	X-ray burn (2 years) after breast amputation	*Staph.* *B. pyocyaneus*	Clean and healthy after 3 weeks' dressing. Clean and slowly granulating when discharged 6th week.
46	10-month-old burn of trunk	*Strep.* *Staph. aureus*	Saturated wet dressings for 2 weeks. Very little change.
86	Infected burn (9 days), finger and hand	*Staph. aureus* and *albus*	Practically healed 15th day. Discharged 22nd day. Wet dressings only twice weekly in clinic.

16 miscellaneous cases infected with gram-positive organisms have been treated with good to excellent results. Soil bacilli extract solution varying from 20–200 γ per cc. was used depending upon the size of the lesion.

Breast Abscesses, Infected Cancer Lesions, etc.

Case No.	Diagnosis.	Microörganism.	Result—Remarks.
2	Recurrent breast abscess	*Staph. aureus* *Strep. hemo.*	Incised, irrigated. Wet packing. Discharged 11th day. Clean, healing.
3	Breast abscess	*Strep. hemo.*	Incised, irrigated. Wet packing. Discharged 10th day. Clean, healing.

Breast Abscesses, Infected Cancer Lesions, etc.—*Continued.*

Case No.	Diagnosis.	Microörganism.	Result—Remarks.
34	Breast abscess. Diabetes	*Staph. aureus*	Incised, irrigated. Wet packing. Discharged 13th day. Clean, healing.
74	Breast abscess. Diabetes	*Strep. hemo.*	Incised, irrigated. Wet packing. Discharged 4th day. Clean, healing.
78	Breast abscess Diabetes	*Strep. hemo.*	Incised, irrigated. Wet packing. Discharged 5th day. Clean, healing.
41	Suppurative arthritis of knee	*Pneumo.* Type III	Incised, irrigated. Wet packing. No pus after 8th day.
50	Suppurative arthritis of knee	*Staph. aureus* *Strep. viridans*	Incised, irrigated. Wet packing. No pus after 10th day.
14	Empyema. Cancer of lung	*Staph.*, *Pneumo.* and *Strep.*	Malodorous pus controlled with irrigations until death from cancer.
12	Fungating fibrosarcoma of thigh	*Staph.*, diphtheroids.	Infection controlled in 16 days.
11	Deep, infected cancer of foot. Diabetes	*Staph.*, *B. pyocy.*	Infection controlled in 14 days.

Hospitalization was shortened in the first seven cases above and the patient made more comfortable in the last three instances.

Adenitis and Suppurative Adenitis.

Case No.	Diagnosis.	Microörganism.
15	Carc. larynx. pharyngitis, Cerv. adenitis	? not operated *
17	Suppurative cervical adenitis	*Staph. aureus*
19	Acute pharyngitis, Cervical adenitis	? not operated *
49	Suppurative axillary adenitis	*Strep. hemolyticus* *Staph. aureus*
55	Suppurative cervical adenitis	*Streptococcus*
56	Suppurative cervical adenitis	*Streptococcus*
67	Suppurative axillary adenitis	*Staph. aureus*
68	Suppurative axillary adenitis	*Staph. aureus*
69	Suppurative axillary adenitis	*Strep. hemolyticus*
81	Suppurative cervical adenitis	*Streptococcus*

* Treated by gargles and atomizer spray.

Of 10 cases of adenitis, eight had progressed to suppuration. These latter ones were incised and drained. Saturated wet dressings (40–100 γ per cc.) were daily placed in the wound after irrigation with similar strengths of soil bacilli extract solution. Suppuration decreased rapidly in all instances and hospitalization was reduced from weeks to days as a general rule.

Infected Abdominal Wounds.

Case No.	Diagnosis.	Microörganism.
1	Infected, ruptured abd. incision	*Strep, B. coli,* Diphtheroids
4	Infected appendectomy, retrocecal	*Strep., Staph., B. pyocyaneus*
5	Infected abdominal wound	*Strep., B. coli*
23	Infected, ruptured abd. incision	*Strep., Staph. aureus*
32	Infected laparotomy wound	*Staph. aureus*
42	Abscess abd. wall	None
44	Retrocecal abscess	*Strep. veridans, anaerobic cocci*
47	Abscess abd. wall	*B. Friedländer*
48	Peritonitis, drainage	*B. coli, Strep.*
51	Abscess abd. wall	*Staph. aureus*
52	Infected cecostomy	*Staph., B. coli, B. pyocyaneus*

The above cases were treated with H-1 solution after having previously received other accepted forms of treatment and responded quickly to the effects of soil bacilli solution. Cases which showed *B. pyocyaneus* (blue pus) were treated with soil bacilli extract solution to which 1 per cent. of acetic acid had been added.

Cellulitis and Suppuration of Extremities.

Case No.	Diagnosis.	Microörganism.
6	Extensive cellulitis, arm	*Strep. hemolyticus*
8	Paronychia, toe	*Staph. aureus*
13	Felon, finger	*Streptococcus*
29	Human bite, finger	*Strep.*, diphtheroids
53	Sloughing cellulitis, foot	*Staph. aureus, Streptococcus*
57	Sloughing cellulitis, foot	*Strep. hemolyticus, Staphylococcus*
58	Cellulitis, thighs	*Strep. hemolyticus*
62	Cellulitis, finger	*Staphylococcus*
63	Cellulitis, finger	*Streptococcus*
64	Cellulitis, foot	*Strep., B. coli*
65	Cellulitis, foot	*Strep. hemolyticus*
66	Infected thigh amputation	*Staph. aureus, B. coli*
72	Sloughing cellulitis, foot	*Strep., Staph.*
73	Cellulitis, leg	*Strep. hemolyticus*
80	Deep bed sore, buttock	*Strep. hemolyticus*
85	Infected Torek operative wound	*Strep., B. pyocyaneus*
86	Infected puncture wound, leg	*Strep., B. pyocyaneus*
88	Cellulitis, arm	*Strep. hemolyticus*
90	Infected finger	*Staphylococcus*

Space does not permit a detailed clinical description of the above cases in which infection was controlled quickly with hastened healing.

These, as well as the other cases, are printed in detail in addenda which may be obtained upon request.

Diabetic Infections.

Case No.	Diagnosis.	Microörganism.
11	Infected carcinoma of foot	*Staph., B. proteus, B. pyocyaneus*
33	Abscesses of arm and back	*Staphylococcus*
34	Breast abscess	*Staph. aureus*
35	Carbuncle and cellulitis of neck	*Staph. aureus, B. pyocyaneus*
36	Multiple abscesses—cellulitis of abdominal wall	*Staph., B. coli, Strep.*
37	Abscess of buttock and back	*Staphyloccocus*
38	Infected thigh amputation	*Strep., B. pyocyaneus*
77	Carbuncles	*Staphylococcus*

Eight diabetic patients with infected lesions were treated with soil bacilli extract solution with very favorable results with the exception of case No. 36. This case did not improve until the underlying cause (osteomyelitis of the symphysis pubis) was later found and adequately treated.

Infected Leg Ulcers.

Six cases of chronic infected leg ulcers (Nos. 22, 26, 27, 43, 45, 84) which had existed from one and one-half to eight years were treated as dispensary cases on alternate days with saturated dressings of H-1 solution (40–100 γ per cc.)

The infections lessened sufficiently within 6–14 days so that gelatin boots could be applied over clean and slowly granulating lesions. However, though soil bacilli extract solution quickly controlled the superficial infection, it had no effect on the conditions causing the chronic ulcers. Nevertheless, it did appear that granulation was stimulated at the wound edges despite the lack of improvement in the main part of the ulcer. At least, infection was controlled and wound healing improved.

Carbuncles.

Four cases (Nos. 35, 39, 61, 77) of carbuncles due to Staphylococci were treated with wet packings of soil bacilli extract solution, 50–100 γ per cc. Two were diabetics, the third (case No. 61) was a 63-year-old psychopathic male with a carbuncle of the thorax. Under nitrous oxide anesthesia his carbuncle was excised and debrided. The lesion was immediately packed with wet gauze saturated with soil bacilli extract solution and daily dressings of the same were insti-

tuted. Seven days later he was transferred from the surgical ward with a clean granulating wound. The two diabetic cases will be referred to elsewhere. Case No. 39 was a 45-year-old female with a carbuncle of the back which was incised and drained with plain gauze saturated in 80 γ solution. It was improved in two days, healing in nine days and healed on the sixteenth day.

Summary.

H-1 solution, a new type of antiseptic obtained from soil bacilli has been found to be harmless to the patient generally and to the tissues locally, when used on external lesions. H-1 has been found to be effective in the treatment of all lesions in which the infecting organisms were gram-positive. H-1 was especially valuable in treating osteomyelitis caused by Staphylococcus when the infected area was adequately exposed surgically and treated with the solution. In the one case of gas gangrene encountered, this antiseptic appeared to be responsible for the successful outcome. It should prove, with adequate surgery and other recognized treatment, to be a helpful adjuvant for the local control of gas gangrene infections. The use of H-1 solution has proved to be of definite value in the control of infected diabetic and ulcerating lesions of cancer. It does not, of course, affect either condition specifically, but it aids in controlling a superimposed infection which always makes either condition worse. Although the ideal germicide has not as yet been found, H-1 solution, as used on external lesions, approaches this in its harmlessness to tissues and its marked bactericidal and bacteriostatic effect on gram-positive organisms which cause most serious infections.

More detailed printed description of the cases will be supplied upon request.

BOOK REVIEWS.

TEMPERATURE MEASUREMENT AND CONTROL, by Robert L. Weber. 430 pages, illustrations, 15 × 22 cms. Philadelphia, The Blakiston Company, 1941. Price $4.00.

Temperature measurement is a subject which bears on all branches of engineering. An increasing number of manufactured products is dependent on accuracy of temperature measurement and efficiency of temperature control. To meet the needs thus arising research has and is contributing newer and better methods which subsequently are developed into practical and specialized apparatus and equipment. On the other hand it is also true that manufacturing processes and technique have resulted from the discovery of means of temperature measurement and control. Therefore a knowledge of the fundamentals, the application of principles, and the construction and operation of apparatus is a valuable tool in industry.

The book at hand has for its purpose "to outline an experimental study of the methods of temperature measurement with the theoretical principles necessary for their appreciation, intelligent use and extension." The material contained in it is first practical, then closely backed with theory of a limited extent sufficient to facilitate understanding of the practical. It is divided into three parts. The first is devoted to a discussion of the principles utilized in temperature measurements such as expansion thermometry, thermoelectric measurements, radiation pyrometry, resistance thermometry, calorimetry, and such special methods as in flame temperature measurement, photothermometry and interferometer measurement of temperature. Principles of high and low temperature are covered. This part of necessity takes up the major portion of the book—some 303 pages. It is presented in the form of a text. The prerequisites are a knowledge of elementary physics with mathematics including the calculus. It is profusely illustrated with diagrams, charts and photographs. At the end of each chapter there is a summary (unusual and of much help), a list of literature references, and problems for exercise.

Part two is devoted to experiments. This resembles somewhat a laboratory manual, describing for each experiment, the object, and procedure. Of extreme importance here is the discussion which adds greatly to the impression to be obtained from the performance of the experiment. There is contained in this part twenty-four experiments involving different temperature measuring methods as well as some theoretical verifications. Part three is an appendix of twenty-four useful tables.

As may be judged from the foregoing, much effort has been made in making the book as self contained as possible, the text, laboratory work, and supplemental information—all between the same two covers. This is in line with the practical nature of the book. The method of presentation, the arrangement of material, and the scope of the book are such as to be of invaluable assistance to students,

practicing engineers and industrial workers who have the necessary prerequisites for its study.

R. H. OPPERMANN.

THE CALCULUS OF EXTENSION, by Henry George Forder. 490 pages, 14 × 22 cms. New York, The Macmillan Company, 1941. Price $6.75.

This book is concerned with the use of an abstract algebra as applied to geometry, by replacing the coordinates in equations representing geometric entities with equations involving geometric entities themselves. To do this, an algebra is constructed employing operations following certain laws of procedure similar to that of Grassmann's calculus of extension.

A logical progression is followed beginning with a setting up of laws and a consideration of them in plane and space geometry, and their application to metric and projective geometry. With regard to the metric, there is shown how the algebra must proceed and with regard to the projective, it is built from the bottom by running it parallel with the algebra and at a few places drawing some work from analytical geometry. An exposition of the algebra is thereby made revealing its power and range. Application of Grassmann's own work is then made in giving a logical systematic account of the algebra in n dimensions.

The calculus can be applied to certain parts of algebra and there is illustrated its use in the theory of determinants. After development of the general theory, there is sketched the theory of matrices, and the application of it to circles and to line geometry. Finally there is introduced and illustrated the notion of algebraic product of geometric entities.

The work goes far in giving appreciation of Grassmann's methods as applied to Geometry. Such knowledge is useful in many instances.

R. H. OPPERMANN.

HIGHER MATHEMATICS FOR ENGINEERS AND PHYSICISTS, by Ivan S. Sokolnikoff and Elizabeth S. Sokolnikoff, second edition. 587 pages, 16 × 24 cms. New York and London, McGraw-Hill Book Co., Inc., 1941. Price $4.50.

While it may be said that mathematics is an indispensible tool of engineering, it does not follow that experienced engineers have little or no difficulty in using this tool efficiently. Physicists too, often find themselves in a situation that only can be relieved by the extraordinary use of perhaps not too well known mathematics. There are many reasons for the existence of this condition. This book attempts to correct it by giving a long range and broad view of mathematics in a realistic sense that emphasizes its practicability, rather than its theoretical aspects. It is in its second edition, and according to the authors, is the outgrowth of a course of lectures offered by one of them to students having a working knowledge of the elementary calculus.

The scope of the treatment is limited to the selection of topics which, in the opinion of the authors, have most frequent and immediate use in applied sciences. The first chapter is devoted to the infinite series, and the plan of coverage here is somewhat illustrative of the methods used in the book in general. The first section brings into sharper focus some of the basic notions of which acquaintance was obtained in the first course in calculus. This is followed by sections on the treatment of the algebra and calculus of series, giving a minimum theoretical

background necessary for the intelligent use of series. Then some of the practical uses of infinite series are indicated.

The next topic is the Fourier series. The wide application of this development of analysis places it in the category that serious consideration must be given to it in a book of this type. Then comes a treatment on the solution of equations which includes a brief outline of some of the algebraic, graphical, and numerical methods of obtaining the real roots of equations with real coefficients of types that occur frequently in the applied sciences. It also contains a short summary of those parts of the theory of determinants and the theory of matrices that are immediately applicable to the solution of systems of linear equations.

Subsequent topics are partial differentiation, multiple integrals, line integral, ordinary differential equations, partial differential equations, vector analysis in which there is a brief and clear development, complex variable, an outline of fundamental facts of the theory of probability, and empirical formulas and curve fitting.

The text is a thorough treatment so far as its purpose is intended. The practical sections or parts of mathematics selected most assuredly make up a good working tool for the engineer or physicist. It is also noted that each of the chapters to a certain extent is self-contained or independent although there is an orderly arrangement and sequence of presentation. Methods of approach to difficult parts reflect experience in teaching this subject.

R. H. OPPERMANN.

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS, by Archer E. Knowlton, Editor-in-Chief. Prepared by a staff of specialists. 2303 pages, illustrations, 16 × 23 cms. New York, McGraw-Hill Book Co., 1941. Price $8.00.

This handbook is now in its seventh edition, the first having been published in 1907, and the sixth in 1933. What practicing electrical engineer does not know "Standard"? What practicing electrical engineer does not know the value of up-to-dateness in a handbook? Since 1933, the date of the previous edition of this handbook, much has transpired in the electrical engineering profession. A handbook, to be a useful tool must contain the basic data on latest developments arranged in an easy to get at fashion. Much effort has been expended to make this edition a quick and ready reference work. Prominent among the changes in this edition is an expansion of the former section on power plant electrical equipment to embrace electrical equipment for the whole power system. This one section thus constitutes a power system handbook in itself. Power transmission, electronics and radio, interior wiring, illumination, prime movers, and telephone are other basic new treatments. Recognition is given to such typically modern developments as air conditioning, electricity in aviation and in the petroleum industry, lightning technology, high voltage generators and cyclotrons. The compilation of codes and standards has been greatly expanded so that users may know where to obtain standard specifications and prescribed practices. The index has been enlarged and entries so selected that it should be possible to locate any topic, even where the mention may be incidental to other subject matter. The book is of a different size and format, more convenient to handle in line with its large content of material.

Electrical engineers will welcome this new edition.

R. H. OPPERMANN.

THE SECOND YEARBOOK OF RESEARCH AND STATISTICAL METHODOLOGY, Books and Reviews, edited by Oscar Krisen Buros. 344 pages, 20 × 28 cms. The Gryphon Press, New Jersey. Price $5.00.

The first yearbook in this series edited by Oscar Krisen Buros was published under the title "Research and Statistical Methodology, Books and Reviews of 1933–1938." It was a bibliographic tool for research workers, the use of which enabled them to gain access to books quickly and efficiently, and at the same time to have at hand an appraisal of the contents of each work. The reception of the first yearbook was so favorable that the editor was encouraged to publish a second yearbook which is the one at hand. It has a more appropriate title and opportunity has been taken to improve it.

The greater part of the work consists of a listing of books of which there are some three hundred and forty-six arranged alphabetically according to author. After a general description of each book, there are reviews from various sources. The yearbook contains one thousand six hundred and fifty-two review excerpts from two hundred and eighty-three Journals. Following this there is a periodical directory which also contains references to the book entries in the previous part of the work. A publisher's directory with index to the books reviewed, an index of titles, an index of names, and a classified index to books according to subject, completes this work.

Research workers seeking information in this field of endeavor will find here an invaluable tool, a means of saving time, a short-cut to completion of their work. Because each book listed contains numerous reviews by different reviewers from different points of view and various sources, an accurate appraisal of the value of each book is obtained. Anyone who has ever done research through the literature will immediately recognize the worth of such a work.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

A Manual of Airbrush Technique, by J. Carroll Tobias. 164 pages, illustrations, 18 × 26 cms. Boston, American Photographic Publishing Co., 1941. Price $3.00.

The Observer's Handbook for 1942, edited by C. A. Chant and F. S. Hogg. 80 pages, illustrations, 14 × 20 cms. Toronto, The Royal Astronomical Society of Canada, 1942. Price $.25 (Twenty-five cents).

Elliptic Cylinder and Spheroidal Wave Functions, by J. A. Stratton, P. M. Morse, L. J. Chu and R. A. Hutner. 127 pages, 22 × 28 cms. New York and London, John Wiley & Sons, Inc. and Chapman & Hall Limited, 1941. Price $1.00.

Anhydrous Aluminum Chloride in Organic Chemistry, by Charles Allen Thomas. 972 pages, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1941. Price $15.00.

Experimental Physical Chemistry, by W. G. Palmer. 321 pages, illustrations, 15 × 23 cms. Cambridge, The University Press, 1941. Price $2.75.

CURRENT TOPICS.

New Forms of Glass Cited as Evidence of Opportunities in Industrial Research.—New forms of glass developed for a wide variety of industrial uses, were cited as evidence of the opportunities existing in the field of industrial research, by Games Slayter, vice-president of the Owens-Corning Fiberglas Corp., Toledo, Ohio, in an address delivered recently before a meeting of the New England Association of Chemistry Teachers at the University of Connecticut, Storrs, Connecticut. Fiberglas, one of the more recent products of industrial research, is entering into our daily lives to a steadily increasing degree, but the role it plays is seldom realized because ninety-nine per cent. of all Fiberglas products go into concealed locations, Mr. Slayter said. The most recent automobile, he pointed out, may contain up to eighty-four individual pieces of manufactured glass in one form or another, but the average driver is not ordinarily conscious of their presence because they are woven into yarns, tapes, braids, and cloth which are used principally for electrical insulation and to provide industry with fabrics that resist heat and corrosive vapors. The present Fiberglas-insulated automobile generator, while no larger than the generator of previous years, supplies fifty per cent. more electrical energy for charging the battery and supplying current for radio and lights. In the form of glass wool, Fiberglas is widely used for thermal insulation in buildings, and household equipment, and to conserve fuel, control heat in industry. The purchaser of a kitchen range, Mr. Slayter said, has a ninety per cent. chance of buying a range with Fiberglas insulation; if he buys a refrigerator, there is a sixty per cent. chance that his refrigerator will be insulated with Fiberglas. Railroad cars, buses, airplanes and ships are also insulated against heat and cold with this wool-like form of glass. Fiberglas yarns as now made have a tensile strength of well over 250,000 pounds per square inch, and in the laboratory Fiberglas yarns with a tensile strength as high as 3,000,000 pounds per square inch have been produced. Mr. Slayter said, "The strongest plastic fibers brought to our attention break at 40,000 pounds per square inch while the best aluminum alloys, we are told break at 65,000 per square inch. To the best of our knowledge, Fiberglas is the strongest of all the tested materials made by either nature or man."

R. H. O.

Continuous Weather Recording Provides Refinery Protection.—NEIL WILLIAMS. (*The Oil and Gas Journal*, Vol. 40, No. 29.) The value of continuous recording of weather data as an adjunct to modern refinery operation was given specific verification by Pan American Refining Corp.'s success in keeping its Texas City, Tex., refinery running during the recent tropical hurricane on the Texas Gulf Coast. The saving effected in prevention of lost time on that occasion alone more than justified the costs and efforts which have been expended by this company since the beginning to provide complete information on atmospheric conditions. Other refineries, as well as other industrial plants, without weather-recording service of their own, and which, on the basis of storm warnings issued by regular weather-reporting agencies, were expected to be in or near the projected path of the storm were shut down, resulting in lost production time of from 24 to 48 hours. Some plants as far away from the path of the storm as Corpus Christi also were shut down as a precaution against the possibility that the storm might veer in their direction. Pan American Refining Corp., with its own weather-information facilities, was posted at all times as to the exact position of the storm, its course and intensity. With this information the company operators were able to pass qualified judgment as to the danger to the refinery and personnel. Operators were prepared to shut down the plant quickly in the event that it was indicated at any time that the plant would be in the direct path of the storm or that the intensity of the storm might make continued operation hazardous. However, it was expected to keep the plant going as long as safely possible. Center of the hurricane passed slightly to the west of Texas City following a northerly course through the immediate Houston district. Maximum wind velocity recorded at the Pan American refinery was 83 miles per hour.

R. H. O.